# *Original Research Article*

**Assessment of Terrestrial Gamma Radiation and Associated Dose Rates from the Naturally Occurring Radionuclides; $^{232}$Th, $^{226}$Ra and $^{40}$K in Nassarawa West, Nigeria**


**Abstract:**

This study assessed the level of terrestrial gammaradiation and associated dose rates from the naturally occurring radionuclide's; $^{232}$Th, $^{226}$Ra and $^{40}$K. Twelve soil sample collected from the respective part of the Nassarawa west were analyzed using the gamma-ray spectrometry Nal (TI) detector system. The mean activity concentration for soil was found to be 483.97 7.32 Bq/kg for $^{40}$K, 28.43 5.30 Bq/kg for $^{226}$Ra and 66.84 2.02 Bq/kg for $^{232}$Th. Aborted Dose Rates in air outdoors were calculated to be between the range of 44.85 nGy/h and 90.71 ngy/h with a mean of 73.68 nGy/h for soil. This value is greater than the world-average of 89nGy/h. Inhabitants of the study areas are subjected to Equivalent Radiation Exposure (Effective Dose Rate) ranging between 0.055 and 0.111 msv/yr with a mean of 0.090msv/y, the results indicated that the observed radiation dose of the terrestrial soil from Nasarawa is minimal and seem to have low exposure for the inhabitant in and around the areas. It is therefore recommend that regular radiation monitoring exercise should be conducted on the processing sites to safeguard the public from high radiation exposure due to direct inhalation of the above mentioned radionuclides.


***Keywords: Soil, Mining, Columbite, Radionuclide, Health Absorbed Dose, Effective Dose, Radium Equivalent Activity, External and Internal Hazard Index and γ-ray Spectrometry.***


## 1. Introduction

The natural terrestrial γ-radiation dose rate is important to the average dose rate received by the world's population (Tso & Leung, 2000; UNSCEAR, 1993).

Estimation of radiation dose distribution is important in assessing the health risk to a population and serve as the reference in documenting changes to environmental radioactivity in soil due to anthropogenic activities (Obed *et al.*, 2005).

Human being is exposed outdoors to the natural terrestrial radiation that originates predominantly from the upper 50cm of the soil (Chikasawa *et al.*, 2001).

Only radioactivity with half-lives comparable with the age of the earth or their corresponding decay products existing in terrestrial material such as $^{232}$Th, $^{226}$Ra and $^{40}$K are of great interest. Since these radionuclides are not uniformly distributed, the knowledge of their distribution in soil and sediments play an important role in radiation protection and measurement (Rani & Singh, 2005).

Gamma radiation from these represents the main external source of irradiation to the human body and the concentrations of these radionuclides in soil are determined by the radioactivity of the rock and nature of the process of the formation of the soils (Orabi *et al.*, 2006; Al-Jundia, 2003).

Therefore, radionuclides in soil generate a significant component of the background radiation exposure to the population (Goddard, 2002).

## 2. Materials and Methods

### 2.1 Materials

In the course of the radiometric study, the following items or materials were used as shown in Table 1.

**Table 1. Materials and their Specifications**

| Materials | Specifications |
|---|---|
| Global Positioning System (G.P.S) | This is a space-based satellite navigation system that provides location and time information in all weather, anywhere or near the earth. This was used to locate the mining sites. |
| Disposable Hand Glove | This is a shielding material used to protect the hands and fingers from contacting any radioactive source. |
| Measuring Tape | This was used to measure the depth of the pit and also to measure the distance between two points. |
| Masking Adhesive Tape | This was used to label the samples for easier identification. |
| Marker pen | This was used to mark the masking tape attached to the polythene bag for easy identification of the soil samples. |
| Polythene Bags | To avoid mixing up of the samples, each of the collected samples were parked into a labeled polythene bag. |
| Sacks | The labeled polythene bags containing the collected samples were parked together into a single sack for easy transportation. |
| Mortar and Pestle | This was used to ground the collected samples after being dried at $60^0$C to $80^0$C for 24 hours in order to maintain the radioactive equilibrium. |
| 5mm-Mesh Sieve | This was used to sieve the grounded samples in order to remove any larger particles in it and make it a powder. |
| Cylindrical Plastic Container | The sieved powder was packed into a cylindrical plastic container and the cover will be sealed with a masking tape to prevent it from any external radiation. |
| Electronic Analytical Balance | The sealed containers were placed on the electronic analytical balance to measure its weight in grams. |
| Cutlass | This was used for clearing of the mining sites also for shallow digging. |
| Sealer | This was used to seal the sieved and labeled samples in their respective container in order to avoid leakage also to prevent the escape of gaseous $^{222}$Rn from the sample. |
| Sodium Iodide-Thalium Gamma Spectroscopic System | This is an instrument set in the laboratory, which was used to analyze the soil samples. |

### 2.2 Study Area

Four villages were chosen in Mararraba-Udege Area. The villages are Eyenu, OPanda, Okereku and Udegen-Mbeki abbreviated as M1, M2, M3 and M4 respectively. The villages M1, M2, M3 and M4 are located at $08^0 24' 38.2'' N$ and $007^0 52' 59.2'' E$, $08^0 21' 24.9'' N$ and $007^0 54' 29.6'' E$, $08^0 24' 04.1'' N$ and $007^0 52' 10.6'' E$ and $08^0 25' 56.3'' N$ and $007^0 53' 49.3'' E$ respectively. Columbite was mined in all the four villages as represented in Figure 1 below:

Figure 3.1 Map Showing Samples Locations in Nasarawa West

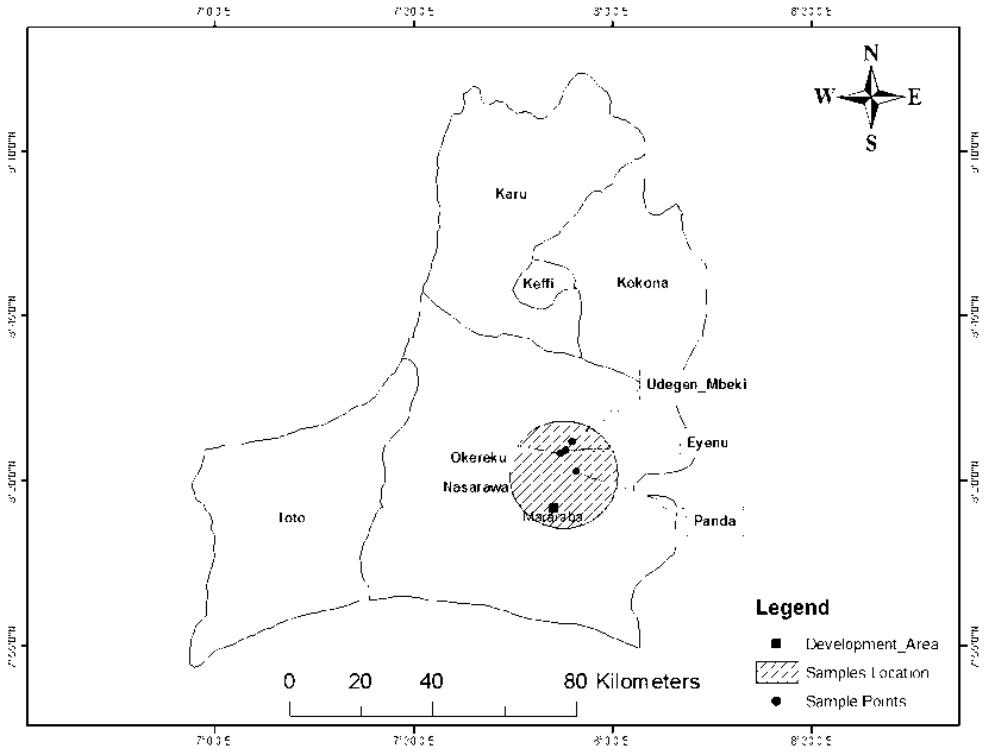



**Fig: 1. Map of Study Area**

## 2.3 Sampling and Analysis

### 2.3.1 Samples Collection

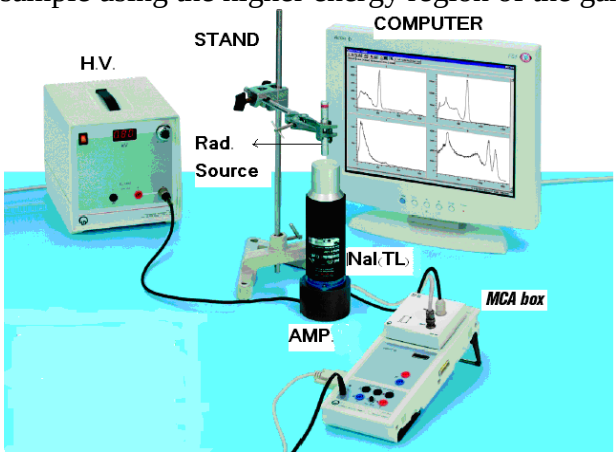
Four sample locations were visited from all over Nasarawa West, Nigeria, to conduct the radiometry study. Three samples will be collected from each sample area to make twelve samples of soil. The samples were collected at 0.5m depth level from the surface of the soil. From each area, as stated earlier, three samples were collected as follows. Firstly from the mining spot, secondly from a distance of 100m away from the mining spot, and thirdly, from the river area within the mining spot. The collected samples were sealed in a labeled polythene bags and enclose into one sack for easiest transportation from the mining or sample point to the house. Meanwhile, when collecting the sample from the mining spot, Global Positioning System (GPS) was used to take the elevation and altitude of the area, and thermometer to measure the atmospheric temperature of the mining spot.

### 2.3.2 Sample Preparation Techniques

The collected samples (soil or sediment) was brought into the laboratory to be left open (if wet) for a minimum of 24 hours to dry under ambient temperature. They will be grounded using mortar and pestle and allowed to pass through 5mm-mesh sieve to remove larger object and make it fine powder. The samples will be packed to fill a cylindrical plastic container of height 7cm by 6cm diameter. This satisfied the selected optimal sample container height. Each container will accommodate approximately 300g of sample. They will be carefully sealed (using Vaseline, candle wax and masking tape) to prevent radon escape and then stored for a minimum of 24 days. This is to allow radium attain equilibrium with the daughters.

### 2.3.3 Sample Analysis

Gamma-ray spectrometry technique was employed in the spectral collection of the prepared sample using the higher energy region of the gamma-lines as shown below;




(Yong *et al.*, 2002).

**Figure 2. A typical Gamma Spectrometry Laboratory**

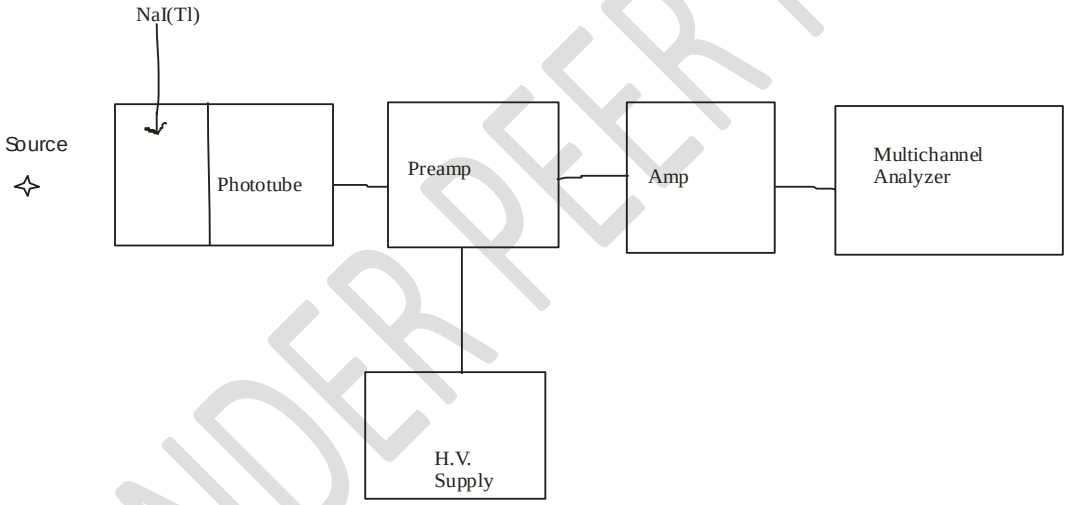



**Figure 3. A block diagram of Gamma Spectrometry.**

## 2.4 Radiation Hazard Indices

The principal primordial radionuclides that would be discuss for all the radiological parameters (Radium Equivalent Activity $Ra_{eq}$, Absorbed Dose Rate, Effective Dose Rate, External Hazard Index $H_{(ex)}$ and Internal Hazard Index $H_{(in)}$) in this case are $^{226}Ra$, $^{232}Th$ and $^{40}K$.

### 2.4.1 Radium Equivalent Activity ($Ra_{eq}$)

The radioactivity of soil samples is determined from $^{226}Ra$, $^{232}Th$ and $^{40}K$ contents. As Radium and its daughter products produce 98.5% of the radiological effects of the uranium series. The contribution from the $^{238}U$ has been replaced with the decay product $^{226}Ra$. Radium Equivalent Activity is an index that has been introduced to represent the specific activities of $^{226}Ra$, $^{232}Th$ and $^{40}K$ by a single quantity. This takes into account the radiation hazards associated with them. This first index, according to AZU (1995), can be calculated using the relation:

$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K$ (1)

where $A_{Ra}$, $A_{Th}$ and $A_K$ are the specific activities of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg, respectively. The $Ra_{eq}$ is related to the external Γ-dose and internal dose due to radon and its daughters. The values must be less than 370Bq/kg, for the area to be acceptable to the public.

### 2.4.2 Absorbed Dose Rate

Conversion Factors to transform specific activities $A_{Ra}$, $A_{Th}$ and $A_K$ of $^{226}Ra$, $^{232}Th$ and $^{40}K$, respectively, in absorbed dose rate at 1meter above the ground (in nGy/hr by Bq/kg) are calculated UNSCEAR (1988) by Monte Caro method as:

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

where $A_{Ra}$, $A_{Th}$ and $A_K$ are the activities of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg, respectively The world average value for the Absorbed Dose Rate is 89nGy/hr for public.

### 2.4.3 Annual Effective Dose Equivalent (AEDE)

The annual effective dose equivalent received outdoor by a person is calculated from the absorbed dose rate by applying dose conversion factor of 0.7 Sv/Gy. Taking into consideration that people on average, spent 20% of their time outdoors, occupancy factor for outdoor and indoor is 0.2 (5/24) and 0.8 (19/24) respectively and according to UNSCEAR (2000) and Veiga *et al.* (2006), AEDE is determined by the equations below.

$AEDE\ (Outdoor)\ (mSv/y) = D\ (nGy/\ h) \times 8760h \times 0.7\ Sv/Gy \times 0.2 \times 10^{-6}$ (3)

And

$AEDE\ (Indoor)\ (mSv/y) = D\ (nGy/h) \times 8760h \times 0.7\ Sv/Gy \times 0.8 \times 10^{-6}$ (4)

The AEDE (indoor) occurs within a house whereby the radiation risks due to building materials only are taken into consideration while AEDE (outdoor) involves a consideration of the absorbed dose emitted from radionuclides in the environment such as $^{226}Ra$, $^{232}Th$ and $^{40}K$. The standard AEDE (Outdoor) value is 0.07 $mSvyr^{-1}$ and that for AEDE (Indoor) is 0.45 $mSvyr^{-1}$. These indices measure the risk of stochastic and deterministic effects in the irradiated individuals.

### 2.4.4 External Hazard Index

Many radionuclides occur naturally in terrestrial soils and rock and upon decay, these radionuclides produces an external radiation field to which human being are exposed in term of dose, the principal primordial radionuclides are $^{226}Ra$, $^{232}Th$ and $^{40}K$. This hazard denoted in terms of External Hazard Index or outdoor radiation hazard index and denoted by $H_{ex}$ according to Arena (1971), can be calculated using the equation:

$$H_{ex} = \frac{Ara}{370} + \frac{Ath}{259} + \frac{Ak}{4810} \leq 1 \quad (5)$$

Where $A_{ra}$, $A_{th}$ and $A_k$ are activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg respectively. The value of the internal hazard index must be less or equal to unity in order for the radiation hazard to be negligibly hazardous to the respiratory organs of the public.

### 2.4.5 Internal Hazard Index

According to Arena (1971), the Internal hazard Index ($H_{in}$) gives the internal exposure to carcinogenic radon and is given by the formula

$$H_{in} = \frac{Ara}{185} + \frac{Ath}{259} + \frac{Ak}{4810} \leq 1 \quad (6)$$

Where $A_{ra}$, $A_{th}$ and $A_k$ are activity concentrations of $^{226}Ra$, $^{232}Th$ and $^{40}K$ in Bq/kg respectively. The value of the internal hazard index must be less or equal to unity in order for the radiation hazard to be negligibly hazardous to the respiratory organs of the public.

## 3. Data Presentation, Result Analysis and Discussion

### 3.1 Data Presentation

This shows the experimental results obtained from the spectra of twelve soil samples under investigation. For the effective computation of the experimental data from Count Dose Rate (cpm) to Exposure Dose Rate ($\mu Svhr^{-1}$), Absorbed Dose Rate ($nGyhr^{-1}$), Annual Effective Dose Rate ($mSvyr^{-1}$), External Hazard Index (Bq/Kg) and Internal Hazard Index (Bq/Kg); Equation 1 to 6 was used and the results are presented in the table below.

**Table 2. Evaluated results for the radiological hazard parameters**

| Sample Codes | k-40 (Bq/kg) | Ra-226 (Bq/kg) | Th-232 (Bq/kg) | Radium Equivalent Activity $Ra_{eq}$ (Bq/kg) | Gamma Absorbed Dose Rate (nGy/h) | Effective Dose Rate (mSv/yr) | External Hazard Index $H_{(ex)}$ (Bq/kg) | Internal Hazard Index $H_{(ex)}$ (Bq/kg) |
|---|---|---|---|---|---|---|---|---|
| **M1 A** | 0569.98±9.95 | 19.35±2.32 | 79.93±1.03 | 177.54 | 80.99 | 0.099 | 0.479 | 0.532 |
| **M1 B** | 0536.39±8.55 | 24.91±0.12 | 67.50±0.11 | 162.74 | 74.65 | 0.091 | 0.439 | 0.507 |
| **M1 C** | 0530.48±9.49 | 33.60±7.18 | 63.06±1.37 | 164.62 | 75.73 | 0.093 | 0.445 | 0.535 |
| **M2 A** | 0239.04±5.60 | 06.49±1.28 | 52.79±1.77 | 100.39 | 44.85 | 0.055 | 0.271 | 0.289 |
| **M2 B** | 0268.27±4.51 | 20.63±5.33 | 42.65±5.25 | 102.27 | 46.47 | 0.057 | 0.276 | 0.332 |
| **M2 C** | 0646.19±5.91 | 35.46±10.78 | 78.45±4.11 | 197.40 | 90.71 | 0.111 | 0.533 | 0.629 |
| **M3 A** | 0048.52±3.58 | 44.96±3.71 | 73.32±0.46 | 153.54 | 67.08 | 0.082 | 0.415 | 0.536 |
| **M3 B** | 0570.30±6.53 | 33.60±6.61 | 65.34±4.79 | 170.95 | 78.70 | 0.097 | 0.462 | 0.552 |
| **M3 C** | 1026.13±7.62 | 18.31±0.48 | 62.71±1.61 | 189.00 | 89.13 | 0.109 | 0.505 | 0.554 |
| **M4 A** | 0537.48±11.2 | 37.89±7.88 | 71.38±2.28 | 181.35 | 83.03 | 0.102 | 0.489 | 0.592 |
| **M4 B** | 283.83±8.40 | 54.58±8.23 | 83.12±0.46 | 195.30 | 87.27 | 0.107 | 0.527 | 0.675 |
| **M4 C** | 551.01±6.53 | 11.36±9.62 | 61.80±1.03 | 142.16 | 65.55 | 0.080 | 0.384 | 0.415 |
| **Range** | **48.52±3.58-1026.13±7.62** | **6.49±1.28-54.58±8.23** | **42.65±5.25-83.12±0.46** | **100.39-197.40** | **44.85-90.71** | **0.055-0.111** | **0.271-0.533** | **0.289-0.675** |
| **Mean** | **483.97±7.32** | **28.43±5.30** | **66.84±2.02** | **161.44** | **73.68** | **0.090** | **0.435** | **0.512** |

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A, B and C represents mining spot, 100 meter away from the mining spot and river area within the mining spot, respectively.

### 3.2 Result Analysis

Table 2 has been split into three (A, B and C, which means mining spot, a hundred metre away from the mining spot and water ways within the mining spot respectively). Three chats has been plotted to analyze the activity concentrations of $^{40}K$, $^{226}R$ and $^{232}Th$ for each table. Finally, the results were compared with the regulatory bodies.

**Table 3. Analysis of Result for Mining Sport**

| Sample Codes | k-40 (Bq/kg) | Ra-226 (Bq/kg) | Th-232 (Bq/kg) | Radium Equivalent Activity $Ra_{eq}$ (Bq/kg) | Gamma Absorbed Dose Rate (nGy/h) | Effective Dose Rate (mSv/yr) | External Hazard Index $H_{(ex)}$ (Bq/kg) | Internal Hazard Index $H_{(ex)}$ (Bq/kg) |
|---|---|---|---|---|---|---|---|---|
| **M1 A** | 0569.98±9.95 | 19.35±2.32 | 79.93±1.03 | 177.54 | 80.99 | 0.099 | 0.479 | 0.532 |
| **M2 A** | 0239.04±5.60 | 06.49±1.28 | 52.79±1.77 | 100.39 | 44.85 | 0.055 | 0.271 | 0.289 |
| **M3 A** | 0048.52±3.58 | 44.96±3.71 | 73.32±0.46 | 153.54 | 67.08 | 0.082 | 0.415 | 0.536 |
| **M4 A** | 0537.48±11.2 | 37.89±7.88 | 71.38±2.28 | 181.35 | 83.03 | 0.102 | 0.489 | 0.592 |

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents mining spot.

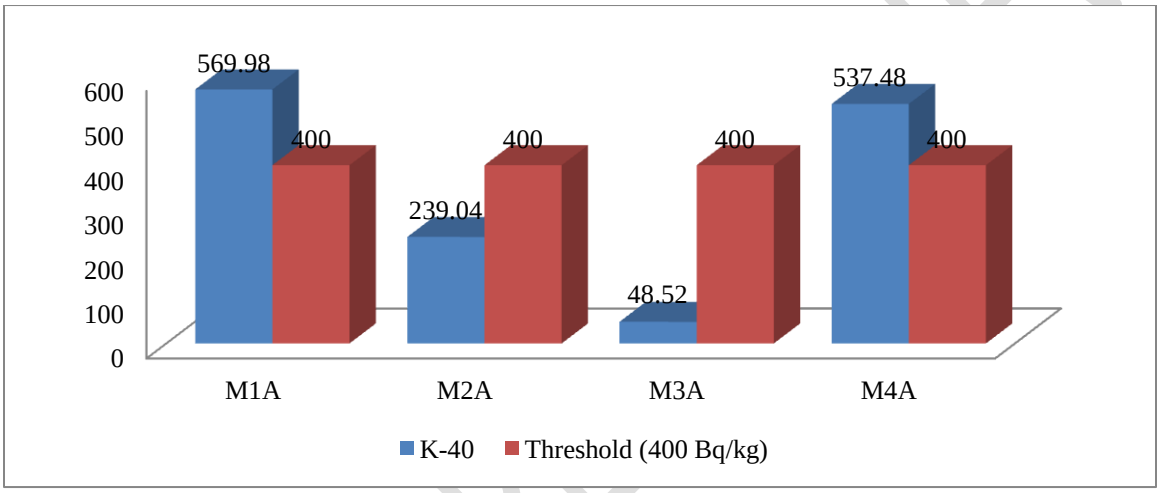



**Figure 4 Comparison of the Spot's Activity Concentration for $^{40}K$ with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents mining spot.

From Figure 4, it is possible to see that, the activity concentration of $^{40}K$ in M2 A and M3 A are lower than the average standard, which 400Bq/kg is recommended by regulatory bodies. While that of M1 A and M4 A is higher.

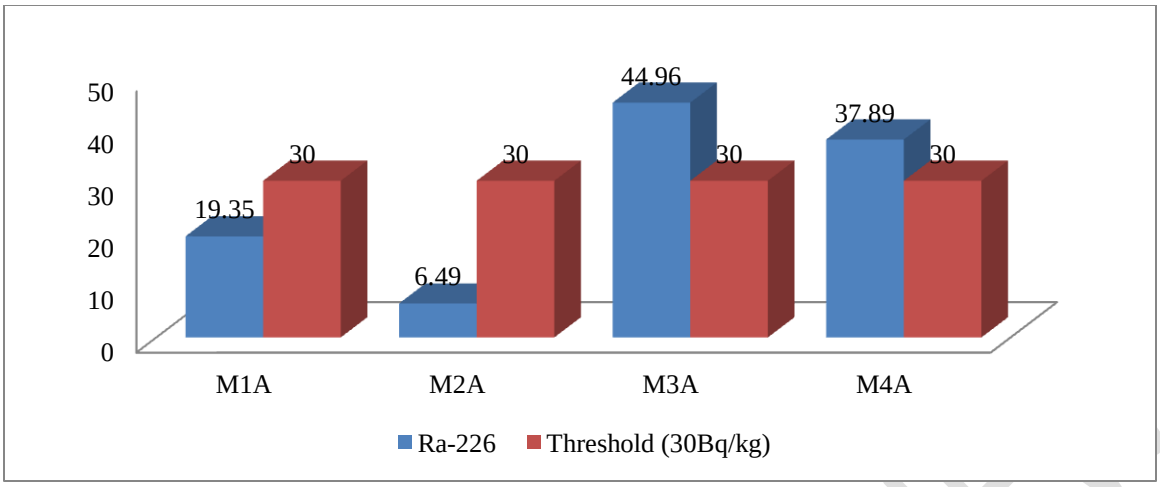



**Figure 5 Comparison of the Spot's Activity Concentration for $^{226}$Ra with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents mining spot.

From Figure 5, it is possible to see that, the activity concentration of $^{226}$Ra for M1 A and M2 A are lower than the average standard, which 30Bq/kg is recommended by regulatory bodies. While that of M3A and M4A are higher.

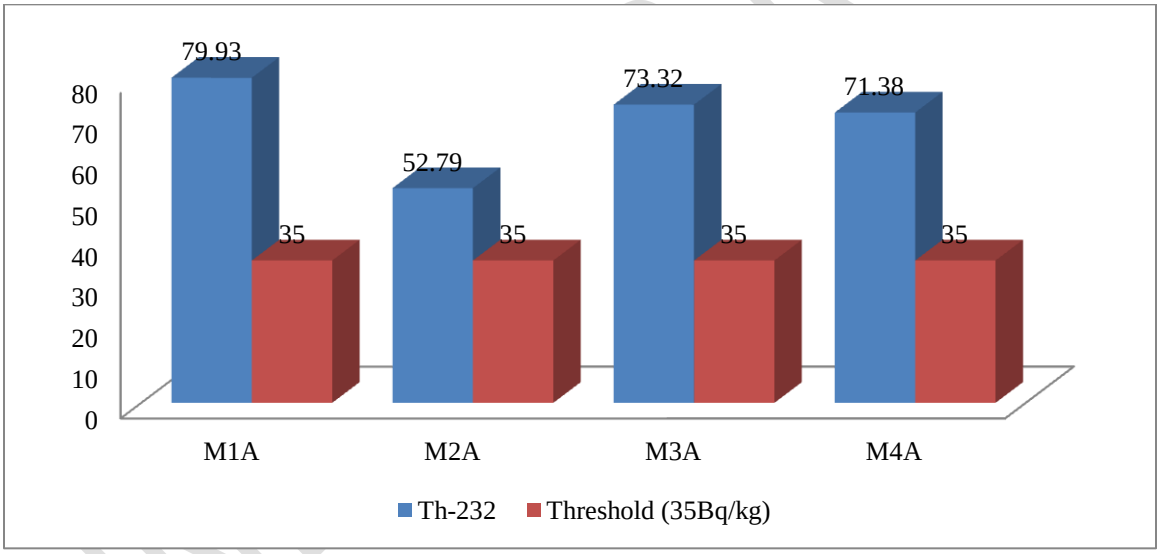



**Figure 6 Comparison of the Spot's Activity Concentration for $^{232}$Th with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents mining spot.

From Figure 6, it is possible to see that, the activity concentrations of $^{232}$Th for all the locations plotted in Figure 6 are higher than the average standard, which 35Bq/kg is recommended by regulatory bodies.

**Table 4. Analysis of Result for Hundred Meters Away**

| Sample Codes | k-40 (Bq/kg) | Ra-226 (Bq/kg) | Th-232 (Bq/kg) | Radium Equivalent Activity $Ra_{eq}$ (Bq/kg) | Gamma Absorbed Dose Rate (nGy/h) | Effective Dose Rate (mSv/yr) | External Hazard Index $H_{(ex)}$ (Bq/kg) | Internal Hazard Index $H_{(ex)}$ (Bq/kg) |
|---|---|---|---|---|---|---|---|---|
| **M1 B** | 0536.39±8.55 | 24.91±0.12 | 67.50±0.11 | 162.74 | 74.65 | 0.091 | 0.439 | 0.507 |
| **M2 B** | 0268.27±4.51 | 20.63±5.33 | 42.65±5.25 | 102.27 | 46.47 | 0.057 | 0.276 | 0.332 |
| **M3 B** | 0570.30±6.53 | 33.60±6.61 | 65.34±4.79 | 170.95 | 78.70 | 0.097 | 0.462 | 0.552 |
| **M4 B** | 283.83±8.40 | 54.58±8.23 | 83.12±0.46 | 195.30 | 87.27 | 0.107 | 0.527 | 0.675 |

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents hundred meters away from the mining spot.

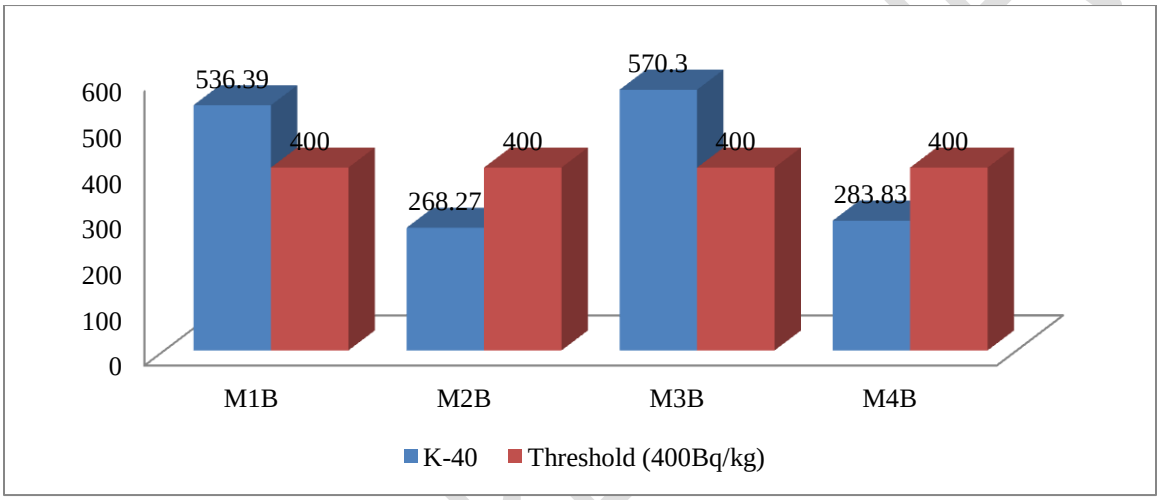



**Figure 7 Comparison of the Hundred Metre's Activity Concentration for $^{40}K$ with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters B represents 100 meter away from the mining spot.

From Figure 7, it is possible to see that, the activity concentration of $^{40}K$ in M2 B and M4 B are lower than the average standard, which 400Bq/kg is recommended by regulatory bodies. While that of M1 B and M3 B is higher.

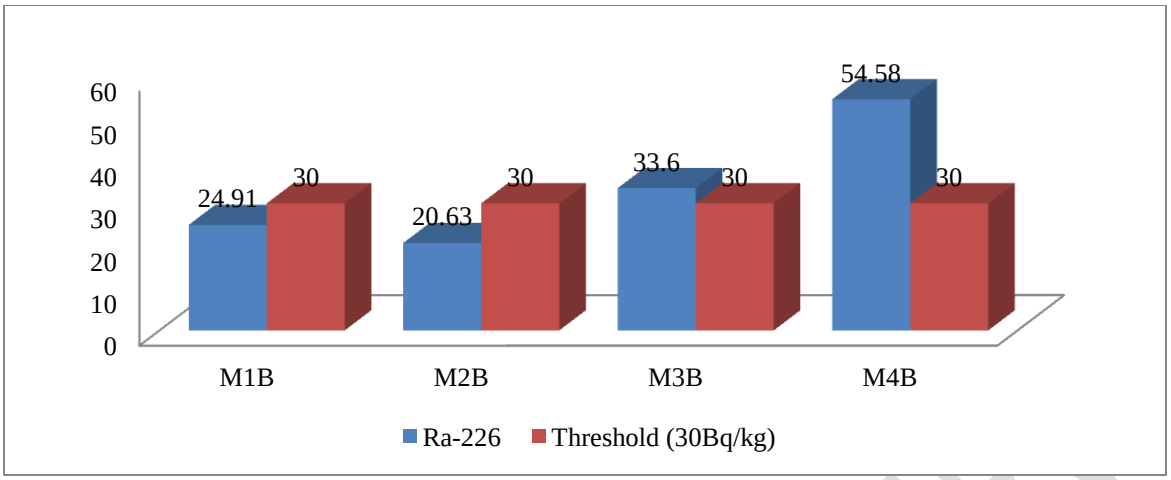



**Figure 8 Comparison of the Hundred Metre's Activity Concentration for $^{226}$Ra with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters B represents 100 meter away from the mining spot.

From Figure 8, it is possible to see that, the activity concentration of $^{226}$Ra for M1 B and M2 B are lower than the average standard, which 30Bq/kg is recommended by regulatory bodies. While that of M3 B and M4 B is higher.

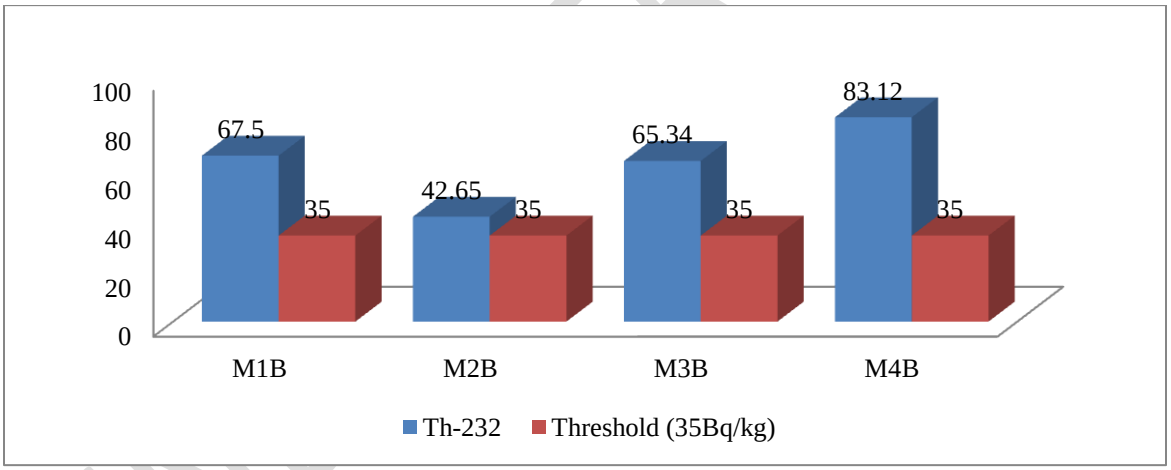



**Figure 9 Comparison of the Hundred Metre's Activity Concentration for $^{232}$Th with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letters A represents hundred meters away from the mining spot.

From Figure 9, it is possible to see that, the activity concentration of $^{232}$Th for all the locations plotted in Figure 9 are higher than the average standard, which is 35Bq/kg recommended by the regulatory bodies.

**Table 5. Analysis of Result for Water Ways**

| Sample Codes | k-40 (Bq/kg) | Ra-226 (Bq/kg) | Th-232 (Bq/kg) | Radium Equivalent Activity $Ra_{eq}$ (Bq/kg) | Gamma Absorbed Dose Rate (nGy/h) | Effective Dose Rate (mSv/yr) | External Hazard Index $H_{(ex)}$ (Bq/kg) | Internal Hazard Index $H_{(ex)}$ (Bq/kg) |
|---|---|---|---|---|---|---|---|---|
| **M1 C** | 0530.48±9.49 | 33.60±7.18 | 63.06±1.37 | 164.62 | 75.73 | 0.093 | 0.445 | 0.535 |
| **M2 C** | 0646.19±5.91 | 35.46±10.78 | 78.45±4.11 | 197.40 | 90.71 | 0.111 | 0.533 | 0.629 |
| **M3 C** | 1026.13±7.62 | 18.31±0.48 | 62.71±1.61 | 189.00 | 89.13 | 0.109 | 0.505 | 0.554 |
| **M4 C** | 551.01±6.53 | 11.36±9.62 | 61.80±1.03 | 142.16 | 65.55 | 0.080 | 0.384 | 0.415 |

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letter C represents the water ways within the mining spot.

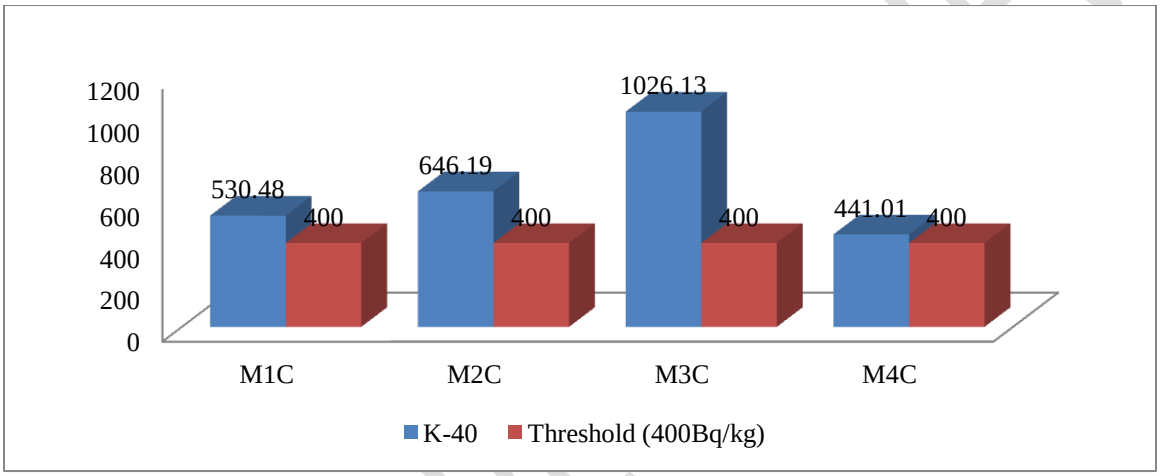



**Figure 10 Comparison of the Water Way's Activity Concentration for $^{40}K$ with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letter C represents the water ways within the mining spot.

From Figure 10, it is possible to see that, the activity concentrations of $^{40}K$ for all the locations plotted in Figure 10 are higher than the average standard, which 400Bq/kg is recommended by regulatory bodies.

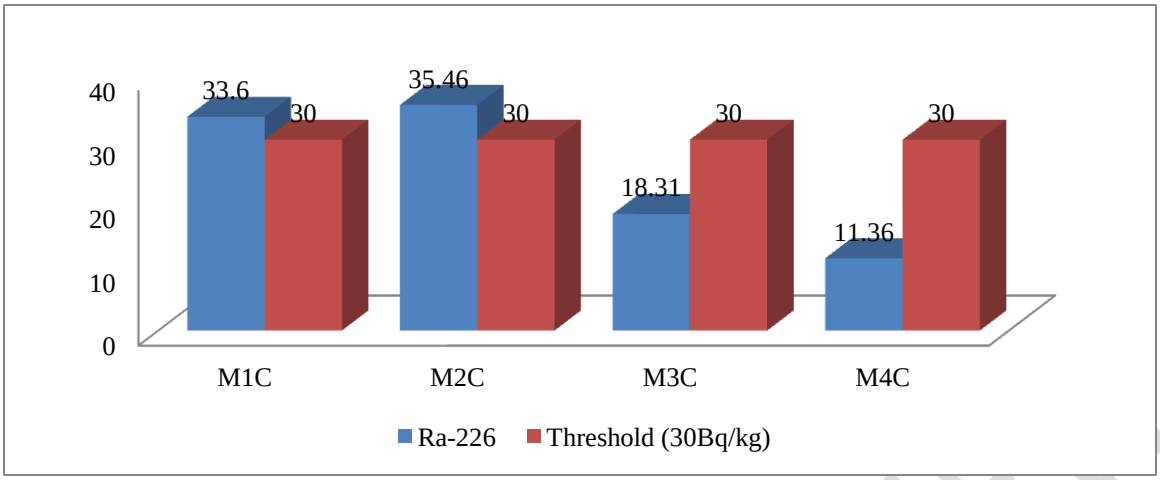



**Figure 11 Comparison of the Water Way's Activity Concentration for $^{226}$Ra with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letter C represents the water ways within the mining spot.

From Figure 11, it is possible to see that, the activity concentration of $^{226}$Ra for M3 C and M4 C are lower than the average standard, which 30Bq/kg is recommended by regulatory bodies. While that of M1 C and M2 C is higher.

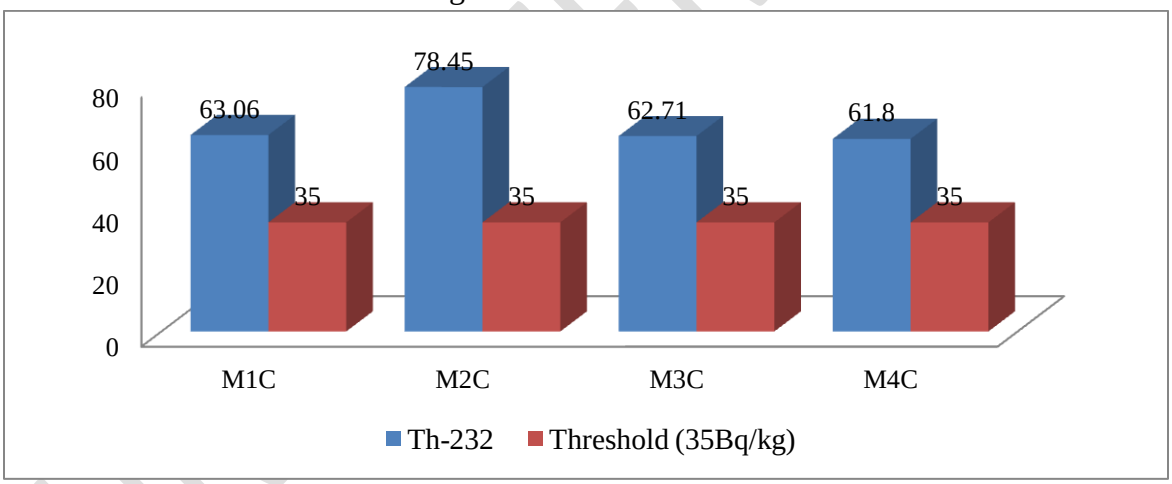



**Figure 12 Comparison of the Water Way's Activity Concentration for $^{232}$Th with Threshold**

Where M1 represent Eyenu, M2 represent Opanda, M3 represent Okereku and M4 represent Udegen-Mbeki. The letter C represents the water ways within the mining spot.

From Figure 12, it is possible to see that, the activity concentrations of $^{232}$Th for all the locations plotted in Figure 12 are higher than the average standard, which 35Bq/kg is recommended by regulatory bodies.

### 3.3 Discussion

The spectra of twelve surface soil samples surrounding the Culombite mine have been analyzed. The specific activity of $^{40}K$, $^{226}Ra$, $^{232}Th$, and Radium equivalent activity ($Ra_{eq}$), Absorbed Dose Rate, Effective Dose Rate, External Hazard Index and Internal Hazard Index are shown in Table 2. The calculated $Ra_{eq}$ values for all samples were also presented in Table 2. It is clearly seen from Table 2 that $Ra_{eq}$ oscillates between 100.39 and 197.40Bq/kg with the mean of 161.438Bq/kg. It is observed that the values of $Ra_{eq}$ in twelve samples were less than the acceptable safe limit of 370Bq/kg recommended by regulatory bodies.

The calculated absorbed dose rate of samples is listed in Table 2. The values are in the range 44.85 to 90.71 with the mean value of 73.68nG/h. With the exception of two samples, all of the remaining values for the gamma absorbed dose rate are higher than the world average of 89nG/h recommended by regulatory bodies.

The values of the effective dose rate in Table 2 for all the samples under investigation ranged from 0.055 to 0.111mSvyr$^{-1}$ with the mean value of 0.090mSvyr$^{-1}$, the values are found to be lower than the average standard of 1mSvyr$^{-1}$ as recommended by regulatory bodies.

Similarly, the External and Internal Hazard Index of the soil samples under investigation ranged from 0.271 to 0.533Bq/kg with the mean of 0.435Bq/kg and 0.2289 to 0.675Bq/kg with the mean of 0.512Bq/kg respectively. These values are found to be lower than the world standard of 1mSvyr$^{-1}$ as recommended by regulatory bodies.

## 4. Summary, Conclusion and Recommendation

### 4.1 Summary

In summary, during the course of my radiometric study, I was opportune to visit four villages of Mararaba-Udege Development Area, Nasarawa West, Nigeria.

Four-sample locations were chosen and for each sample location, three sample points were chosen. These sample points are, the mining spot, 100 meter away from the mining spot and the nearby river area, and are coded A, B and C respectively. These make twelve samples collected from all the selected mining areas during the radiometric study.

The principal primordial radionuclides in the samples are $^{226}Ra$, $^{232}Th$ and $^{40}K$. The activity concentration of the above-mentioned radionuclides was analyzed.

Further calculation was carried out and the results were compared with the worldwide limits for all the radiological parameters.

### 4.2 Conclusion

A Sodium Iodide-Thalium Gamma Spectroscopy System has been used to assess the terrestrial gamma radiation and associated dose rates from the naturally occurring radionuclides; $^{232}Th$, $^{226}Ra$ and $^{40}K$ in NassarawaWest, Nigeria.

The activity profile of the raidionuclides has clearly showed the existence of low-level activity in some of the places and high-level activity in some other places of the studied area. For the radiological hazard parameters, it was found that, the gamma absorbed dose rate is higher in some places while in some of the places it is found to be lower. Meanwhile, other radiological

hazard parameters like Radium equivalent activity, effective dose rate, and external and internal hazard index are found to be lower for all the samples under investigation.

### 4.3 Recommendation

In the course of this radiometric study, it was discovered that some places are subjected to high activity concentration and gamma absorbed dose rate. These areas with high level of radiation need regulatory control. The level of radiation in those areas is sufficiently high and can cause radiological hazard to the public of the area. Further investigation is needed to safeguard the areas with low-level radiation.

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