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# Assessment of Natural Radioactivity Level and Radiation Hazard from Soils Used as Major Material for Building in Lere Sheet 147, North Central Nigeria

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**Abstract**
Natural radionuclides ($^{238}$U, $^{232}$Th and $^{40}$K) content of soil commonly used as building material in Lere Sheet 147, North Central Nigeria have been determined using RS-230 Gamma Ray Spectrometer. The results show that the mean concentration of $^{238}$U, $^{232}$Th, and $^{40}$K in the soils is 7.53 ppm, 28.93 ppm and 1.94 % respectively, while the mean activity concentration for each of these radionuclides is 92.97, 117.46 and 608.31 Bq kg$^{-1}$for $^{238}$U, $^{232}$Th and $^{40}$K respectively. The calculated average value for radium equivalent activity for the soils is 307.78 Bq kg$^{-1}$ which is lower than the permitted value of 370 Bq/Kg, while the average external and internal hazard indices are 0.83 and 1.08 respectively. The annual effective dose equivalent (internal and external), are less than 1 mSvy$^{-1}$, thus suggesting that radiological hazard parameters of the soils are generally lower than their respective precautionary limits. In terms of radiological safety, the soils from the study area are safe for use as building material.
**Keywords:** Soils. Uranium. Thorium. Potassium. Activity Concentration. Radiation hazards. Lere Sheet 147.

## 1. Introduction

Soil is the part of the earth's surface composed of disintegrated rock and humus that provides the medium for plant growth. Apart from agricultural purpose, soil is an important material commonly used for residential buildings, especially in rural areas in Nigeria. The formation of soils is aided by climate, topography, biological factors as well as time, and their composition reflects the chemical composition of the parent rocks. In most rural settlements such as those in Lere Sheet 147 in North Central Nigeria, conventional building materials are not readily available and are often too expensive for the locals to afford. Soils on the other hand are directly available and at relatively much lower cost. Soil is particularly preferred when clayey because clay serves as binder thus reducing the use of cement. The use of in-situ materials for building is also important, socially as it provides job to local workers.

Soils are, however a potential source of indoor radioactivity because of the naturally occurring radionuclides in them (Laith *et al*. 2015). All products derived from rock (sands, soils, clays, aggregates and boulders) contain various amounts of uranium ($^{238}$U), thorium ($^{232}$Th) and potassium ($^{40}$K) which are radioactive. They are the principal sources of the external and internal radiation exposures in buildings. Radioelements concentration in building materials is important in assessing population exposures, as most individuals spend 70-80% of their time indoors. The objectives of the present study therefore are to assess the natural radioactivity in soils used for building dwelling in selected towns located within Lere Sheet 147 ($^{238}$U, $^{232}$Th and $^{40}$K) using Gamma Ray Spectrometry, and to assess the radiological hazards to human health. The data obtained could serve as critical components in the formulation of new Federal Building Code in Nigeria. It will be useful for the development of standards and guidelines on the use and management of building materials in relation to radioactivity, which is currently lacking. According to Afolayan *et al*. (2008) and Anosike (2011), the existing Federal Building Code only stipulates that application of all materials and components used in the construction of buildings must achieve aesthetics, durability, functionality, character and affordability. These authors have recommended that locally available building materials should be integrated for their additional advantages of availability, identity, job creation and affordability.

## 2. Materials and Methods

### *2.1 The study area*

Lere Sheet 147 is bounded by Latitudes 10.0° N and 10.5° N, and Longitudes 8.5°E and 9.0°E. It is located in North Central Nigeria and covers an area of about 3025 Km$^2$. Settlements in the area are mainly rural and dispersed, characteristic of most parts of Northern Nigeria. Lere Sheet 147 is underlain by rocks of the Basement Complex as well as those of the Younger Granite Complex. The basement rocks are composed of mainly migmatites, porphyritic granites and granite gneiss. They occur mainly in the western, northern and north central parts, and are well deformed. The Younger Granite ring complexes here comprises the Amo, Buji, Jere-Sanga, Rukuba and Saiya-Sokobo Complexes (Figure 1). The Amo Complex is located north of Rukuba Complex and consists of several successions of ring-intrusions, leading to the formation of a variety of biotite granites. The

Complex hosts varying amount of cassiterite. The Buji Complex is located east of Amo Complex. It comprises of two superimposed ring complexes one made up entirely of volcanic rocks, and the other of granitic rocks. The volcanic cycle consists of early rhyolites, tuffs and agglomerates, late intrusive rhyolites, quartz hedenbergite porphyry as well as quartz feldspar porphyry, while the granitic cycle consists of aegirine microgranite, Buji biotite granite and Gurum albite riebeckite granite. The Jere - Sanga Complex is located north of Amo Complex and it displays both the plutonic and volcanic cycles of intrusion leading to the formation of various types of biotite granites, late intrusive rhyolites, early rhyolites, tuffs and breccias. Tin and columbite mineralization are common within this Complex. The Rukuba Complex is located to the south of Amo Complex and consists of two overlapping plutons of biotite granite, covered by large basalt flow at the central part (Macleod *et al*. 1971). The Complex is equally rich in columbite and alluvial tin. The Saiya-Shokobo Complex lies north of Jere-Sanga Complex. Lithological units of the Complex comprises of dolerites and gabbro, alkali-feldspar syenite, pre-caldera agglomerates and ignimbrites, basalts, quartz porphyry, arfvedsonite granite porphyry, crystal rich ignimbrites, arfvedsonite granite and biotite granite. Weathering processes arising from high temperature and rainfall have resulted in production of thick lateritic soil in most places.

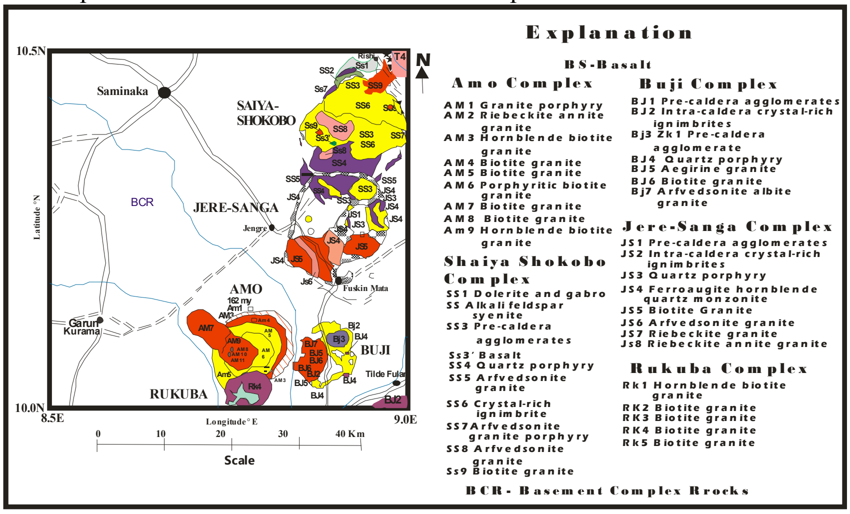


Figure 1. Geological Map of Lere Sheet 147, North Central Nigeria
(Map modified after Kinnaird et al (1981).

***2.2 Determination of radioelements in the soils***

In-situ measurement of gamma radiation was carried out on the soils using RS-230 Gamma Spectrometer (Figure 2). It is a handheld auto-stabilized 1024 channel spectrometer which uses a large (103 $cm^3$) BGO (Bismuth Germanate Oxide) detector for improved level of system sensitivity and accuracy. The use of a BGO gives very significant increase in performance over the normal NaI detector. A preset time of 120 seconds was used for the measurement per point to allow for better accuracy, while the assay mode provided the concentrations of Potassium (K %), equivalent Thorium (eTh) in ppm, and equivalent Uranium (eU) in ppm for each point of measurement. Three (3) measurements were taken at each of the 46 sites, and the average values obtained. The location of the measurement points are as shown in Figure 3.


Figure 2. RS-230 BGO Handheld Gamma-Ray Spectrometer.

 

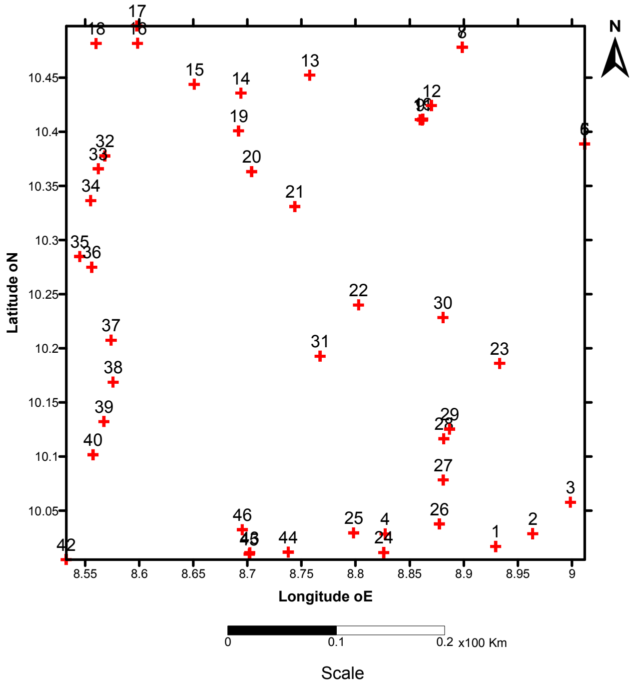


Figure 3. Location of measurement points within Lere Sheet 147 North Central Nigeria.

## 3. Results and Discussion

### *3.1 Radioelement concentration and Specific Activity.*

Concentration of $^{238}$U, $^{232}$Th and $^{40}$K measured from the soils vary from 4.50-11.70ppm, 22.30-36.20 ppm, and 1.30-2.70 % respectively (Table 1). The concentration of $^{238}$U is generally higher in soils in the basement rocks terrain around Saminaka and Lere areas to the northwest, as well as within the Rukuba, Buji and parts of Jere-Sanga Complexes to the south east (Figure 4). Lower values of $^{238}$U were generally recorded in the basement rocks around Ganji, Jengre and Katako areas in the central part consisting of granite gneiss, as well as within the Saiya-Shokobo Complex. The Saiya-Shokobo Complex has high proportion of quartz porphyries which are known to have low radioelement concentration. The $^{232}$Th concentration appears to be generally higher within the Younger Granites compared to the areas underlain by rocks of the Basement Complex (Figure 5). Granitic rocks are known to be enriched in Th and U with an average value of 15 µg/g Th and 5 µg/g U (Faure 1986, Mènager *et al*. 1993) compared to rocks of basaltic or ultramafic composition with values of (< 1 µg/g U). Potassium is generally more evenly distributed in the various lithologies found in the study area (Figure 6). Activity concentration was calculated by multiplying the radionuclides concentration presented in Table 1 with the conversion factors shown in Table 2. Results obtained vary from 55.58-144.50 Bq/Kg for $^{238}$U, 90.54-146.97 Bq/Kg for $^{232}$Th, and 406.90-845.10 Bq/Kg for $^{40}$K (Table 3). Average values of activity concentration for the three radionuclides are 92.97 Bq/Kg, 117.46 Bq/Kg, and 608.31 Bq/Kg respectively.

 

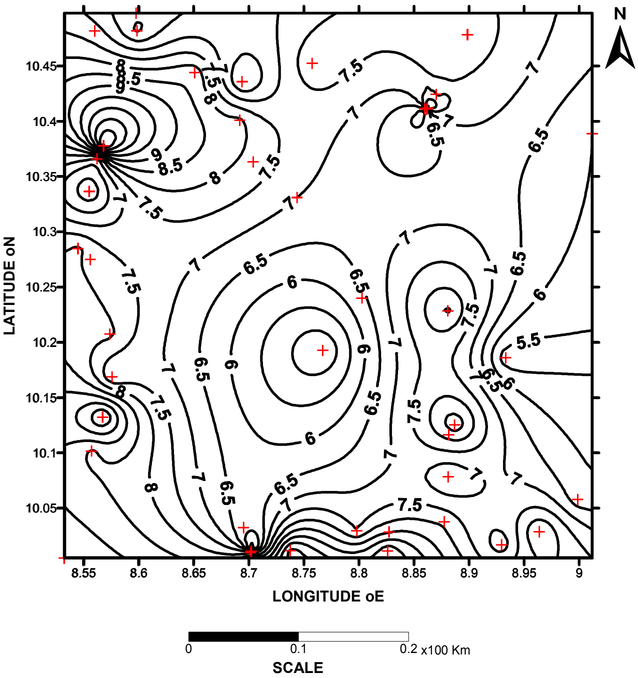


Figure 4. Distribution of Uranium in soils within Lere Sheet 147, North Central Nigeria.

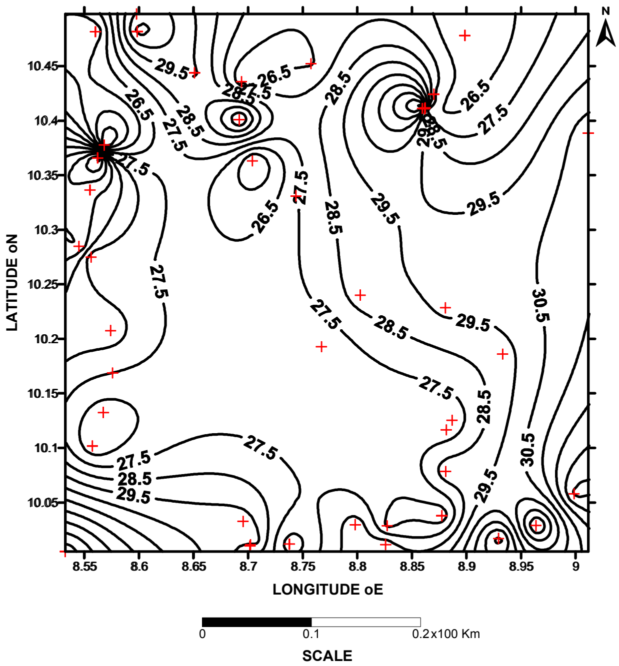


Figure 5. Distribution of Thorium in soils of Lere Sheet 147, North Central Nigeria.

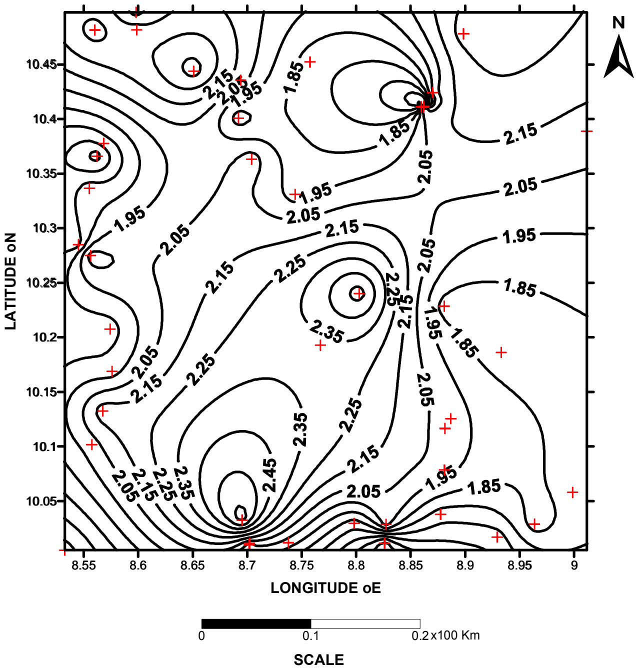


Figure 6. Distribution of Potassium in soils within Lere Sheet 147, North Central Nigeria.

Table 1. Radionuclides concentration in soils from selected areas in Lere Sheet 147, North Central Nigeria

| SNo | Town | COORDINATE | | U (ppm) | Th (ppm) | K % | SNo | Town | COORDINATE | | U (ppm) | Th (ppm) | K % |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAT $^0$N | LON $^0$E | | | | | | LAT $^0$N | LON $^0$E | | | |
| 1 | Babale | 10.02 | 8.93 | 6.70 | 34.00 | 1.60 | 24 | Gurum Padok | 10.01 | 8.83 | 9.90 | 29.20 | 1.30 |
| 2 | Narabi | 10.03 | 8.96 | 8.60 | 26.20 | 1.90 | 25 | Kartan kaye | 10.03 | 8.80 | 7.50 | 29.10 | 1.70 |
| 3 | T. Fulani | 10.06 | 9.00 | 6.20 | 34.80 | 1.80 | 26 | Mista Alli | 10.04 | 8.88 | 7.90 | 25.90 | 1.70 |
| 4 | Zarau | 10.03 | 8.83 | 8.40 | 26.20 | 2.00 | 27 | R.Gwamna | 10.08 | 8.88 | 6.50 | 29.20 | 2.00 |
| 5 | Zarau | 10.39 | 9.01 | 6.00 | 31.20 | 2.10 | 28 | Saiya | 10.12 | 8.88 | 8.20 | 26.90 | 2.00 |
| 6 | Rishi | 10.39 | 9.01 | 5.40 | 34.40 | 2.00 | 29 | Zabolo | 10.13 | 8.89 | 8.90 | 26.90 | 2.00 |
| 7 | Wundi | 10.48 | 8.90 | 7.80 | 25.50 | 2.30 | 30 | B. Karwa | 10.23 | 8.88 | 8.60 | 29.80 | 1.80 |
| 8 | Tsoma | 10.48 | 8.90 | 9.40 | 28.00 | 2.00 | 31 | Katako | 10.19 | 8.77 | 4.50 | 26.70 | 2.30 |
| 9 | Yargi BH | 10.41 | 8.86 | 6.20 | 35.00 | 1.50 | 32 | Kaura | 10.38 | 8.57 | 11.70 | 22.30 | 1.70 |
| 10 | Yargi1 | 10.41 | 8.86 | 9.00 | 29.20 | 1.50 | 33 | Lere | 10.37 | 8.56 | 6.70 | 34.00 | 1.50 |
| 11 | Yargi 2 | 10.41 | 8.86 | 6.20 | 25.90 | 2.30 | 34 | Madugu | 10.34 | 8.56 | 5.60 | 30.70 | 1.80 |
| 12 | Yargi 3 | 10.42 | 8.87 | 7.40 | 27.50 | 2.00 | 35 | Mal.Gure | 10.28 | 8.55 | 8.10 | 31.50 | 1.70 |
| 13 | Maresu | 10.45 | 8.76 | 7.90 | 26.40 | 1.80 | 36 | Bar.Kaswa | 10.27 | 8.56 | 7.80 | 27.70 | 2.10 |
| 14 | Ang.Male | 10.44 | 8.69 | 5.90 | 25.60 | 2.10 | 37 | K.Kurama | 10.21 | 8.57 | 8.10 | 29.10 | 1.80 |
| 15 | Saminaka | 10.44 | 8.65 | 8.30 | 29.60 | 2.40 | 38 | G.Kurama | 10.17 | 8.58 | 7.00 | 27.50 | 1.90 |
| 16 | T.Kayerda | 10.48 | 8.60 | 5.90 | 31.90 | 2.20 | 39 | Yardi | 10.13 | 8.57 | 10.60 | 26.00 | 2.20 |
| 17 | Kayerda | 10.50 | 8.60 | 6.10 | 30.70 | 2.00 | 40 | Warsa Piti | 10.10 | 8.56 | 8.40 | 25.70 | 2.00 |
| 18 | Kampany F. | 10.48 | 8.56 | 7.20 | 24.80 | 2.30 | 41 | Mariri | 10.03 | 8.53 | 7.70 | 32.00 | 1.90 |
| 19 | Saminaka | 10.40 | 8.69 | 8.10 | 32.70 | 1.80 | 42 | Damak Kas | 10.01 | 8.53 | 9.50 | 36.20 | 1.50 |
| 20 | Krosha | 10.36 | 8.70 | 7.80 | 24.30 | 2.10 | 43 | Binchi | 10.01 | 8.70 | 5.00 | 30.50 | 2.00 |
| 21 | Ganji | 10.33 | 8.74 | 7.00 | 27.50 | 1.90 | 44 | Binchi | 10.01 | 8.74 | 10.20 | 25.80 | 1.90 |
| 22 | Jengre | 10.24 | 8.80 | 6.40 | 29.00 | 2.60 | 45 | Binchi | 10.01 | 8.70 | 8.60 | 28.60 | 1.90 |
| 23 | Fuska Mata | 10.19 | 8.93 | 5.20 | 29.10 | 1.80 | 46 | Isanchi | 10.03 | 8.70 | 6.20 | 30.00 | 2.70 |
| SUMMARY | | | | | | | | | AVERAGE | | 7.53 | 28.93 | 1.94 |
| | | | | | | | | | MINIMUM | | 4.50 | 22.30 | 1.30 |
| | | | | | | | | | MAXIMUM | | 11.70 | 36.20 | 2.70 |

Table 2. Conversion factors from equivalent concentration (ppm, %) to activity concentration in Bq/kg (IAEA 1989).

| | | |
|---|---|---|
| 1% K | 313 Bq/kg | $^{40}$K |
| eU (ppm) | 12.35 Bq/kg | $^{238}$U or $^{226}$Ra |
| eTh (1ppm) | 4.06 Bq/kg | $^{232}$ Th |

Table 3. Activity concentration of $^{238}$U, $^{232}$Th and $^{40}$K in soils within Lere Sheet 147, North Central Nigeria.

| SNo | Town | COORDINATE | | U | Th | K | SNo | Town | COORDINATE | | U | Th | K |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | LAT ⁰N | LON◦E | (Bq/kg) | (Bq/kg) | (Bq/kg) | | | LAT ◦N | LON◦E | (Bq/kg) | (Bq/kg) | (Bq/kg) |
| 1 | Babale | 10.02 | 8.93 | 82.75 | 138.04 | 500.80 | 24 | Gurum | 10.01 | 8.83 | 122.27 | 118.55 | 406.90 |
| 2 | Narabi | 10.03 | 8.96 | 106.21 | 106.37 | 594.70 | 25 | Kartankaye | 10.03 | 8.80 | 92.63 | 118.15 | 532.10 |
| 3 | T. Fulani | 10.06 | 9.00 | 76.57 | 141.29 | 563.40 | 26 | Mista Alli | 10.04 | 8.88 | 97.57 | 105.15 | 532.10 |
| 4 | Zarau | 10.03 | 8.83 | 103.74 | 106.37 | 626.00 | 27 | R.Gwamna | 10.08 | 8.88 | 80.28 | 118.55 | 626.00 |
| 5 | Zarau | 10.39 | 9.01 | 74.10 | 126.67 | 657.30 | 28 | Saiya | 10.12 | 8.88 | 101.27 | 109.21 | 626.00 |
| 6 | Rishi | 10.39 | 9.01 | 66.69 | 139.66 | 626.00 | 29 | Zabolo | 10.13 | 8.89 | 109.92 | 109.21 | 626.00 |
| 7 | Wundi | 10.48 | 8.90 | 96.33 | 103.53 | 719.90 | 30 | B. Karwa | 10.23 | 8.88 | 106.21 | 120.99 | 563.40 |
| 8 | Tsoma | 10.48 | 8.90 | 116.09 | 113.68 | 626.00 | 31 | Katako | 10.19 | 8.77 | 55.58 | 108.40 | 719.90 |
| 9 | Yargi BH | 10.41 | 8.86 | 76.57 | 142.10 | 469.50 | 32 | Kaura | 10.38 | 8.57 | 144.50 | 90.54 | 532.10 |
| 10 | Yargi1 | 10.41 | 8.86 | 111.15 | 118.55 | 469.50 | 33 | Lere | 10.37 | 8.56 | 82.75 | 138.04 | 469.50 |
| 11 | Yargi 2 | 10.41 | 8.86 | 76.57 | 105.15 | 719.90 | 34 | Madugu | 10.34 | 8.56 | 69.16 | 124.64 | 563.40 |
| 12 | Yargi 3 | 10.42 | 8.87 | 91.39 | 111.65 | 626.00 | 35 | Mal.Gure | 10.28 | 8.55 | 100.04 | 127.89 | 532.10 |
| 13 | Maresu | 10.45 | 8.76 | 97.57 | 107.18 | 563.40 | 36 | Bar.Kaswa | 10.27 | 8.56 | 96.33 | 112.46 | 657.30 |
| 14 | Ang.Male | 10.44 | 8.69 | 72.87 | 103.94 | 657.30 | 37 | K.Kurama | 10.21 | 8.57 | 100.04 | 118.15 | 563.40 |
| 15 | Saminaka | 10.44 | 8.65 | 102.51 | 120.18 | 751.20 | 38 | G.Kurama | 10.17 | 8.58 | 86.45 | 111.65 | 594.70 |
| 16 | T.Kayerda | 10.48 | 8.60 | 72.87 | 129.51 | 688.60 | 39 | Yardi | 10.13 | 8.57 | 130.91 | 105.56 | 688.60 |
| 17 | Kayerda | 10.50 | 8.60 | 75.34 | 124.64 | 626.00 | 40 | Warsa Piti | 10.10 | 8.56 | 103.74 | 104.34 | 626.00 |
| 18 | KampanyF. | 10.48 | 8.56 | 88.92 | 100.69 | 719.90 | 41 | Mariri | 10.03 | 8.53 | 95.10 | 129.92 | 594.70 |
| 19 | Saminaka | 10.40 | 8.69 | 100.04 | 132.76 | 563.40 | 42 | Damak Kas | 10.01 | 8.53 | 117.33 | 146.97 | 469.50 |
| 20 | Krosha | 10.36 | 8.70 | 96.33 | 98.66 | 657.30 | 43 | Binchi | 10.01 | 8.70 | 61.75 | 123.83 | 626.00 |
| 21 | Ganji | 10.33 | 8.74 | 86.45 | 111.65 | 594.70 | 44 | Binchi | 10.01 | 8.74 | 125.97 | 104.75 | 594.70 |
| 22 | Jengre | 10.24 | 8.80 | 79.04 | 117.74 | 813.80 | 45 | Binchi | 10.01 | 8.70 | 106.21 | 116.12 | 594.70 |
| 23 | Fuska Mata | 10.19 | 8.93 | 64.22 | 118.15 | 563.40 | 46 | Isanchi | 10.03 | 8.70 | 76.57 | 121.80 | 845.10 |
| SUMMARY | | | | | | | | | AVERAGE | | 92.97 | 117.46 | 608.31 |
| | | | | | | | | | MINIMUM | | 55.58 | 90.54 | 406.90 |
| | | | | | | | | | MAXIMUM | | 144.50 | 146.97 | 845.10 |

### *3.2 Radiological risk assessment*

On the basis of measured concentrations of $^{238}$U, $^{232}$Th and $^{40}$K, and the calculated activity concentration of the respective radionuclides, radiation health to the exposed community through the use of soils from the study area for residential building, were evaluated via the following hazard parameters:-

#### *3.2.1 Absorbed Dose Rate in Air*

The absorbed dose rate in the air due to gamma rays 1 metre above the ground was calculated according to Beretka & Mathew (1985), and UNSCEAR (2000) using Equation 1.

$$D\ (nGy/h) = 0.462A_U + 0.621A_{Th} + 0.0417A_K \quad (1)$$

Where 0.462, 0.621 and 0.0417 are the conversion factors for $^{238}$U, $^{232}$Th and $^{40}$K respectively. Here it is assumed that contributions from other natural radionuclides are negligible. Results obtained vary from 123.01–165.05 nGy/h, with an average of 141.26 nGy/h. This is high considering a recommended limit of 55 nGy/h (UNSCEAR, 1988).

#### *3.2.2 Annual Effective Dose Equivalent (AEDE)*

Annual effective dose equivalents (indoor and outdoor) were calculated for the soils using Equation 2 and 3.

$$AEDE_{Indoor}\ (mSvy^{-1}) = D\ (nGyh^{-1}) \times 8760\ hy^{-1} \times 0.75 \times 0.7SvGy^{-1} \times 10^{-6} \quad (2)$$

$$AEDE_{Outdoor}\ (mSvy^{-1}) = D\ (nGyh^{-1}) \times 8760\ hy^{-1} \times 0.75 \times 0.7SvGy^{-1} \times 10^{-6} \quad (3)$$

Where D is the absorbed dose in air, 8760 (*24x365*) is the number of hours in a year, 0.75 is the indoor occupancy factor, which represents the fraction of time spent indoor, and 0.7$SvGy^{-1}$ is the conversion coefficient from absorbed dose in air to effective dose received by adults. UNSCEAR (1993) recommended 0.8 (19.2 hrs) as the indoor occupancy factor while it is estimated that an adult spends an average of 18 hours indoors per day in the study area. Thus the indoor occupancy factor is 0.75. Annual effective dose equivalents obtained is 0.57-0.76 mSv/y (indoor) and 0.19-0.25 mSv/y (outdoor).

#### *3.2.3 Hazard Indices*

The internal hazard and external hazard indices are reflections of exposure to radiation. The hazard indices were calculated using Equation 4 and 5 according to Shoeib & Thabayneh (2014).

$$H_{In} = A_U/185 + A_{Th}/259 + A_K/4810 \quad (4)$$

$$H_{Ex} = A_U/370 + A_{Th}/259 + A_K/4810 \quad (5)$$

Where $A_U$, $A_{Th}$ and $A_K$ are the specific activity concentrations of $^{238}$U, $^{232}$Th and $^{40}$K respectively. The mean internal and external hazard index should be less than 1 to provide an acceptable level of safety for humans living in this type of buildings. Internal hazard index for the soils is 0.87-1.30 (indoor), and 0.72-0.98 (outdoor).

#### *3.2.4 Radium Equivalent Activity ($Ra_{eq}$)*

It is an established fact that distribution of $^{238}$U, $^{232}$Th, and $^{40}$K are not uniform in soils, rocks and most environmental samples. In view of this, Radium Equivalent Activity ($Ra_{eq}$) is normally used to obtain a weighted sum of the activity concentrations of the $^{238}$U, $^{232}$Th and $^{40}$K in any material. It assesses the gamma radiation hazards to human associated with those radioelements. Radium equivalent activity was calculated according to Beretka & Matthew (1985); UNSCEAR (2000) as follows:

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.43A_{Th} + 0.077A_K \quad (6)$$

Where $A_{Ra}$, $A_{Th}$ and $A_K$ are the specific activity concentrations of uranium ($^{238}U$), thorium ($^{232}Th$) and potassium ($^{40}K$) respectively. This equation is based on the estimation that 370 Bq/kg of $^{238}U$, 259 Bq/kg of $^{232}Th$ and 4810 Bq/kg of $^{40}K$ produce the same gamma ray dosage. For safety reasons, maximum permissible value of $Ra_{eq}$ is set at 370 Bq/kg. This is equivalent to a maximum permissible dose of 1.5mSv/y to human from exposures to natural radiation. The result obtained in soils from the study area is 266.02-363.65 Bq/kg with an average of 307.78 Bq/kg.

### *3.2.5 Excess Lifetime Cancer Risk (ELCR)*

Excess lifetime cancer risk estimates the additional or extra risk of developing cancer due to exposure to a toxic substance incurred over the lifetime of a person. Excess life-time cancer risk (ELCR) was calculated from the annual effective dose equivalent data obtained, and according to Ramasamy *et al*. (2009) and Emelue *et al*. (2014) using the equation 7 and 8.

$$ELCR_{(indoor)} = AEDE(indoor) \times DL \times RF \quad (7)$$

$$ELCR_{(outdoor)} = AEDE(outdoor) \times DL \times RF \quad (8)$$

Where AEDE is the annual effective dose equivalent, DL is the average duration of life (70 years), and RF is the risk factor or fatal cancer risk per Sievert. The International Committee on Radiation Protection ICRP (1991) has pegged RF at 0.05 for the public. The values obtained range from 1.98 $x10^{-3}$- 2.66 $x10^{-3}$ (indoor) while for outdoor, it is from 0.66 $x10^{-3}$- 0.89 $x10^{-3}$.

## 4. Conclusion

In-situ soil assay for $^{238}U$, $^{232}Th$, and $^{40}K$, and activity concentrations in forty-six selected sites in Lere Sheet 147 in North Central Nigeria was carried out using the RS-230 Gamma Ray Spectrometer. Mean concentration of $^{238}U$, $^{232}Th$, and $^{40}K$ was 7.53 ppm, 28.93 ppm and 1.94% while the mean activity concentration was 92.97 Bq $kg^{-1}$, 117.46 Bq $kg^{-1}$, and 608.31 Bq $kg^{-1}$ for $^{238}U$, $^{232}Th$, and $^{40}K$ respectively. The mean activity concentrations for these radionuclides are higher than the world average of 33, 45, and 420 Bq $kg^{-1}$ respectively for soil, as provided by UNSCEAR (1998, 2000). The values are also higher than those obtained for soil in other parts of the world. The calculated average value for $Ra_{eq}$, was 307.78 Bq $kg^{-1}$. By contrast, the values of $H_{ex}$ and $H_{in}$, for the soils were 0.83, and 1.08, respectively and are generally below their respective precautionary limits as set by UNSCEAR. Furthermore, annual effective dose equivalent of 0.57-0.76 mSv $y^{-1}$ (internal) and 0.19-0.25 mSv $y^{-1}$ (external) calculated for the soils are below safety standard of 1.0 mSv $y^{-1}$set by ICRP. The overall results showed that soils in the Lere Sheet 147, North Central Nigeria are radiologically safe as a major material for residential building.

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