

## Evaluation of Activity Concentrations of $^{238}\text{U}$ , $^{232}\text{Th}$ , and $^{40}\text{K}$ in Soil Samples from North-western Yobe

<sup>\*1</sup>Mustapha Bukar Liberty, <sup>2</sup>Abbati Alhaji Musa, <sup>3</sup>Mohammed Audu,  
<sup>4</sup>Samaila Ibrahim, <sup>5</sup>Yakubu Musa

<sup>1,2,3,4,5</sup>Department of Science Laboratory Technology; Mai Idris Aloomo Polytechnic  
P.M.B. 1020 Geidam, Yobe State

\*Corresponding Author: [mbukarliberty@gmail.com](mailto:mbukarliberty@gmail.com)  
+2348065597143

### Abstract

The activity concentrations radionuclides ( $^{238}\text{U}$ ,  $^{232}\text{Th}$  and  $^{40}\text{K}$ ) from the thirty (30) different soil samples in North-western Yobe, in Yobe state, Nigeria were evaluated. The activity concentrations in these samples were measured through gamma spectroscopy with a Thallium activated Sodium Iodide NaI (TI) detector. The activity concentrations in the thirty samples measured, ranged between  $50.47 \pm 0.6$  to  $97.12 \pm 2.8$  Bq kg<sup>-1</sup> for  $^{238}\text{U}$ ,  $62.32 \pm 1.5$  to  $98.11 \pm 2.4$  Bq kg<sup>-1</sup> for  $^{232}\text{Th}$ , and  $125.30 \pm 0.8$  to  $205.70 \pm 2.7$  Bq kg<sup>-1</sup> for  $^{40}\text{K}$  and their respective mean values of  $79.02 \pm 2.7$  Bq kg<sup>-1</sup>,  $83.22 \pm 2.7$  Bq kg<sup>-1</sup>, and  $168.02 \pm 2.7$  Bq kg<sup>-1</sup>. While, the annual effective dose rate was estimated, is in the range of 92.30 to 137.44  $\mu\text{Sv y}^{-1}$  with an average value of 115.13  $\mu\text{Sv y}^{-1}$ .

**Key words:** Activity concentration, Absorbed dose rate, Annual effective dose rate, Gamma Spectroscopy, Radionuclides.

## 1. Introduction

The naturally occurring radioisotopes Uranium ( $^{238}\text{U}$ ), Thorium ( $^{232}\text{Th}$ ), their decay products and natural Potassium ( $^{40}\text{K}$ ) that exists depending on the geological formations and geochemical characteristics of those materials at different regions of the Earth's environment in varying concentrations (Kang, T.-W et. al 2024).

Natural radioactivity is spread in the environment in various formations such as soil, sediment, water, plants and air. The main radioactive substances contained in the environment are long-life radionuclides known as NORMs (Naturally Occurring Radionuclide Materials), especially  $^{238}\text{U}$  ( $^{226}\text{Ra}$ ) series,  $^{232}\text{Th}$  series and  $^{40}\text{K}$ . Humans are continuously exposed to ionizing rays emitted by a radioactive substance that can come from external and internal sources. External sources are in the form of terrestrial radiation and cosmic rays' radiation, while internal sources come from radioactive substances that enter the body along with the entry of food, drinks and breathing (Singh J et al. 2009) The estimated average radiation dose received by the world population 85% comes from natural radioactivity while the remaining ~15% comes from artificial sources. (John, S. O. O et. al 2025) The total dose received by the population in a particular area depends on the content of radioactive NORMs present in the area. Land is a source of sustained exposure to radiation in humans and also as a medium for the transfer of radioactive substances to other environmental media, therefore an analysis of the activity concentration of radioactive substances in the soil is particularly importance to estimate the total and effective doses received by the community in certain areas (Mubarak F, Fayeze-Hassan M, Mansour NA, Ahmed TA and Ali A 2017).

Activity concentrations of these natural radionuclides in soil determine natural radioactivity level and imminence of this activity could pose potential health hazard. (Muhammad, A., & Abbasi, A. 2025).

Therefore, the assessment of gamma radiation dose from natural sources is of particular importance as natural radiation is the largest contributor to the external dose of the world population. (UNSCEAR 2008). North western Yobe (Gashua, Yusufari, Jajimaji, Nguru, and Machina) being one of the strategic regions in Yobe and it has large number of inhabitants living in these towns of the region, their health is of paramount importance.

## 2. Materials and Methods

### 2.1 Study Area

North western part of Yobe state, Nigeria, that comprises five (5) local government areas (Bade, Yusufari, Karasuwa, Nguru, Machina), where the headquarters of these local government are selected for sample collection being they are most populated areas in the respective local government areas.

### 2.2 Sample Preparation

Thirty (30) soil samples to be collected in thirty different sample points across the towns, that is six (6) samples in each of the five local government areas. Samples are to be collected from about 20 cm deep from the surface of the soil; each weigh approximately 1.0 kg, and it to be considered representative of the sampling sites. Each sample to be packed inside a container and label.

### 2.3 Analysis

These samples are to left open to dry and then taken to laboratory for analysis. The major nuclear technique employed in the analysis of samples for background activity is the Gamma spectrometry using NaI(Tl) detector.

All samples were counted for 172,700 seconds to obtain better statistics, and thus reduce statistical uncertainty. The background spectra were used to correct the net peak area of gamma rays for the measured isotopes. The activity concentrations per unit mass A (Bq/Kg) of each

sample were calculated using the following formula:

$$A = \frac{P}{\epsilon f_{\gamma} t m}$$

where P is the total net counts under the above-mentioned photo-peak, after correcting for the background and Compton contributions,  $\epsilon$  is the measured photo-peak efficiency,  $f_{\gamma}$  is the gamma ray intensity, t is the sample measurement time, and m is the sample weight. The error calculations for activity were determined with a quadratic formula, and the results were presented together with the measurement results.

The contribution of the natural radionuclides to the absorbed dose rate in air (D) depends on the concentration of the radionuclides in the soil. The dose can be calculated using absorbed dose rate conversion factors depending on the radionuclides in the soil. The conversion factors described by UNSCEAR (2000) were adopted.

#### 2.4 The absorbed dose rates D (nGy h<sup>-1</sup>)

The gamma absorbed dose rates D (nGy h<sup>-1</sup>) were calculated using the following formula:

$$D \text{ (nGy h}^{-1}\text{)} = 0.462 A_U + 0.604 A_{Th} + 0.0417 A_K$$

where D is the dose rate at 1 m above the ground, and A<sub>U</sub>, A<sub>Th</sub>, and A<sub>K</sub> are the activity concentrations (Bq kg<sup>-1</sup>) of <sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K respectively, in the soil sample (Saito & Jacob, 1995).

#### 2.5 Annual effective dose rate (D<sub>eff</sub>)

The gamma absorbed doses in nGy h<sup>-1</sup> were converted to annual effective dose in mSv y<sup>-1</sup>, as proposed by UNSCEAR (2000). The annual effective dose rate (D<sub>eff</sub>) was computed using the following equation:

$$D_{\text{eff}} \text{ (}\mu\text{Sv y}^{-1}\text{)} = D \text{ (nGy h}^{-1}\text{)} \times 8760 \text{ (hy}^{-1}\text{)} \times 0.2 \times 0.7 \text{ (SvGyh}^{-1}\text{)} \times 10^{-3}$$

where D is the absorbed dose rate in air (nGy h<sup>-1</sup>), 0.7 is the dose conversion factor (SvGyh<sup>-1</sup>), 0.2 is the outdoor occupancy factor, and 8760 is the time conversion factor (hy<sup>-1</sup>).

### 3. Results and Discussion

Table 1. The activity concentrations in (Bq kg<sup>-1</sup>) in the soil samples.

Activity Concentration (Bq Kg <sup>-1</sup> )			
Sample	<sup>238</sup> U	<sup>232</sup> Th	<sup>40</sup> K
S1	68.72 ± 1.3	85.08 ± 1.5	175.62 ± 2.3
S2	95.01 ± 1.6	83.10 ± 1.1	190.10 ± 1.7
S3	63.12 ± 0.9	78.20 ± 1.4	171.62 ± 1.5
S4	95.12 ± 2.0	96.28 ± 1.0	192.55 ± 2.0
S5	72.55 ± 1.4	85.43 ± 0.9	168.57 ± 1.5
S6	85.92 ± 2.3	86.46 ± 1.3	186.70 ± 2.4
S7	60.57 ± 1.0	71.05 ± 1.7	190.46 ± 2.9
S8	66.87 ± 1.2	90.73 ± 1.9	165.87 ± 2.1
S9	88.94 ± 1.9	88.26 ± 1.3	186.60 ± 1.9
S10	95.73 ± 1.1	90.56 ± 1.0	205.70 ± 2.7
S11	86.50 ± 2.1	87.33 ± 1.7	145.00 ± 1.7
S12	97.12 ± 2.8	62.32 ± 1.5	143.66 ± 2.4
S13	63.75 ± 0.8	80.23 ± 2.2	176.25 ± 2.2
S14	66.40 ± 0.9	94.78 ± 0.6	125.30 ± 0.8

Evaluation of Activity Concentrations of <sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K in Soil Samples from North-western Yobe

S15	95.45 ± 1.1	70.45 ± 1.7	154.12 ± 1.3
S16	96.30 ± 2.4	98.03 ± 1.9	200.73 ± 2.3
S17	90.40 ± 2.0	71.21 ± 2.5	160.28 ± 2.2
S18	50.47 ± 0.6	75.80 ± 1.8	146.30 ± 2.0
S19	90.31 ± 2.1	79.30 ± 1.1	176.80 ± 1.6
S20	60.51 ± 1.4	95.00 ± 2.3	166.81 ± 1.9
S21	94.20 ± 1.0	80.12 ± 1.2	123.20 ± 2.2
S22	85.30 ± 2.2	74.61 ± 1.8	145.31 ± 2.1
S23	52.36 ± 1.8	80.20 ± 1.0	137.25 ± 1.1
S24	92.65 ± 3.2	80.24 ± 1.8	164.70 ± 0.9
S25	70.54 ± 1.6	87.71 ± 1.5	171.40 ± 2.6
S26	89.47 ± 2.0	98.11 ± 2.4	152.90 ± 1.5
S27	86.30 ± 1.3	70.81 ± 1.1	150.14 ± 1.7
S28	92.34 ± 2.1	80.11 ± 0.9	198.30 ± 3.0
S29	64.82 ± 2.4	79.28 ± 1.6	180.62 ± 2.1
S30	59.35 ± 1.6	95.66 ± 2.1	187.82 ± 1.8
Mean	79.24	83.22	168.02

Table 2. Absorbed dose rates, and annual effective dose rates of the soil samples

Sample	D (nGyh <sup>-1</sup> )	D <sub>eff</sub> (μSv y <sup>-1</sup> )
S1	90.46	110.94
S2	102.00	125.11
S3	83.55	102.46
S4	110.10	135.06
S5	92.14	113.01
S6	99.71	122.28
S7	78.84	96.69
S8	92.61	113.58
S9	102.20	125.31
S10	107.50	131.84
S11	98.76	121.12
S12	88.50	108.54
S13	85.26	104.56
S14	93.15	114.24
S15	93.08	114.15
S16	112.10	137.44
S17	91.46	112.17
S18	75.20	92.23
S19	96.99	118.95
S20	92.29	113.19
S21	97.05	119.02
S22	90.53	111.03

S23	78.35	96.09
S24	98.14	120.36
S25	92.71	113.70
S26	107.00	131.19
S27	88.90	109.03
S28	99.32	121.80
S29	85.36	104.69
S30	93.03	114.09
Mean	93.88	115.13

The activity concentrations of radionuclides of ten (30) soil samples measured ranged from  $50.47 \pm 0.6$  to  $97.12 \pm 2.8$  Bq kg<sup>-1</sup> with mean value of 79.24 Bq kg<sup>-1</sup> for <sup>238</sup>U,  $62.32 \pm 1.5$  to  $98.11 \pm 2.4$  Bq kg<sup>-1</sup> with mean value of 83.22 Bq kg<sup>-1</sup> for <sup>232</sup>Th and  $125.30 \pm 0.8$  to  $205.70 \pm 2.7$  Bq kg<sup>-1</sup> with mean value of 168.02 Bq kg<sup>-1</sup> for <sup>40</sup>K as in Table 1. The comparison of activity concentrations of the three radionuclides is shown Figure 1.

Mean activity concentration of <sup>238</sup>U determined in this study is greater than the global average of 35 Bq kg<sup>-1</sup>, average activity concentration of <sup>232</sup>Th is higher than the global average of 30 Bq kg<sup>-1</sup>, but for average activity concentration of <sup>40</sup>K is less than to that global average 400 Bq kg<sup>-1</sup> (UNSCEAR, 2000).

The absorbed dose rate D (nGyh<sup>-1</sup>) in air at 1 m above the ground surface due to the radioactivity concentration of <sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K (Bq kg<sup>-1</sup>) in the collected samples ranged between 75.20 to 112.10 nGyh<sup>-1</sup> with an average value of 93.88 nGyh<sup>-1</sup> for the thirty samples. It is greater than world average of 59 nGyh<sup>-1</sup> as reported by (UNSCEAR, 2000).

The annual effective dose rate (D<sub>eff</sub>) was estimated, it ranged from 92.30 to 137.44 μSv y<sup>-1</sup> with an average of 115.13 μSv y<sup>-1</sup>, which was higher than that of world average of 70 μSv y<sup>-1</sup> (UNSCEAR, 1988).

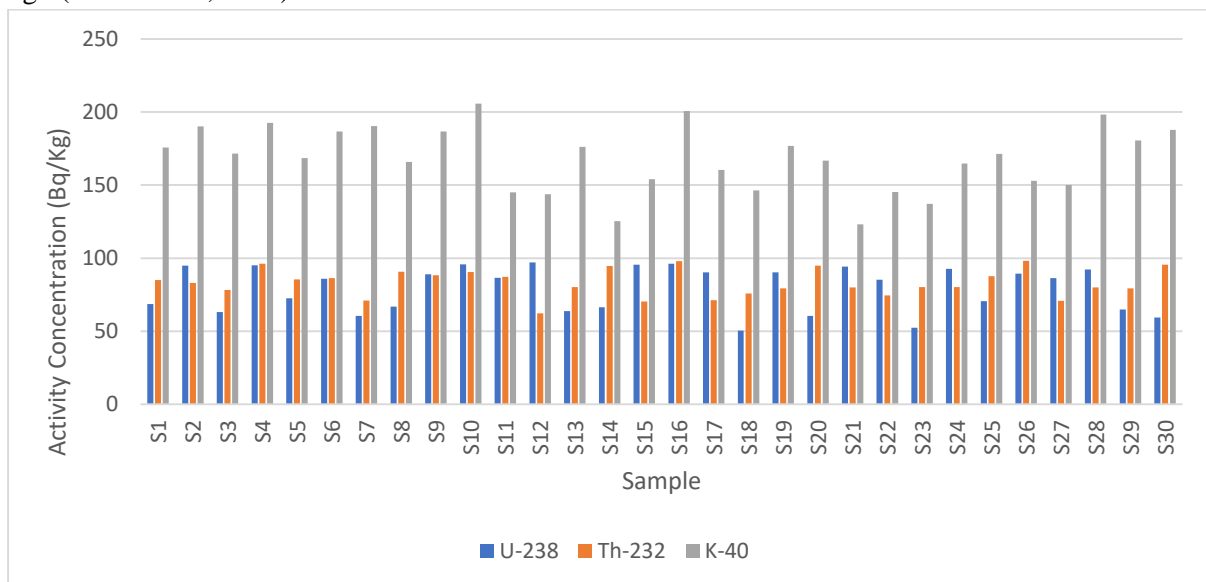


Figure 1: Comparison of the activity concentrations of <sup>238</sup>U, <sup>232</sup>Th, and <sup>40</sup>K in the soil samples

#### 4. Conclusions

The average activity concentrations of  $^{238}\text{U}$  and  $^{232}\text{Th}$  for the soil samples are greater than the world mean values. However, the mean activity concentrations for  $^{40}\text{K}$  for the samples is below the world mean value, which might connect to

#### Acknowledgement

We acknowledge tertiary education trust fund (TETFUND) Abuja, for the support rendered throughout this research and also appreciation goes Mai Idris Aloomo Polytechnic, Geidam, Yobe state.

#### References

- Ahmad, N., Jaafar, M. S., Bakhsh, M., & Rahim, M. (2015). An overview on measurements of natural radioactivity in Malaysia. *Journal of Radiation Research and Applied Sciences* 8(1), 136e141.
- John, S. O. O., Olukotun, S. F., & Mathuthu, M. (2025). Assessment of Radioactivity Concentrations and Associated Radiological Health Risk in Natural Spring Mineral Bottled Drinking Water from South Africa. *Water*, 17(2), 156.
- Kang, T.-W., An, M., Han, Y.-U., Yang, H. J., Kang, T., Jung, S., Lee, W.-S., & Park, W.-P. (2024). Activity Concentration of Natural Radionuclides in Surface Sediments of Major River Watersheds in Korea and Assessment of Radiological Hazards. *Water*, 16(20), 2897.
- Mubarak F, Fayez-Hassan M, Mansour NA, Ahmed TA. and Ali A. (2017) Radiological Investigation of High Background Radiation Areas *J. Nat. Lib. Of Medicine* Published online.
- Singh S, Rani A, Mahajan RK. 226Ra, 232Th and 40K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry. *Radiat Meas*, 39:431-9.
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). (2000). *Sources and effects of ionizing radiation: UNSCEAR 2000 report to the General Assembly, with scientific annexes (Vol. I)*. New York, NY: United Nations.
- United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). (2008). *Sources and*
- the acidity of the soil as a result of agricultural activities (pesticides, herbicides, fertilizers etc.) applications in the study area as the inhabitants there, are predominantly farmers. Repeating similar assessment of activity concentration is suggested for the study area.
- using gamma ray spectrometry. *Radiat Meas*, 39:431-9.
- Muhammad, A., & Abbasi, A. (2025). Determination of natural radioactivity concentrations and risk assessment in soil from mining sites in Minna environs, Niger State, Nigeria. *Journal of Radioanalytical and Nuclear Chemistry*, 334(11), 4021–4029.
- Saito, K., & Jacob, P. (1995). Gamma ray fields in the air due to sources in the ground. *Radiation Protection Dosimetry*, 58, 29-45.
- Singh J, Singh H, Singh S, Bajwa B S and Sonkawade R G (2009). Comparative study of natural radioactivity in soil samples from the Upper Siwaliks and Punjab India using gamma ray spectrometry *J. Env. Radioactivity* 100 p.94-98.
- Singh S, Rani A, Mahajan RK. (2005). 226Ra, 232Th and 40K analysis in soil samples from some areas of Punjab and Himachal Pradesh, India using gamma ray spectrometry. *Radiat Meas*, 39:431-9.

*effects of ionizing radiation:  
UNSCEAR 2008 report to the  
General Assembly, with scientific  
annexes (Vol. I). New York, NY:  
United Nations.*