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# STATISTICAL ANALYSIS OF TERRESTRIAL GAMMA RADIATION DOSE RATES IN RELATION TO DIFFERENT SOIL TYPES IN SOUTHERN KATSINA STATE, NIGERIA

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***ABSTRACT***
***The composition of soil makes it radioactive, the steller materials from which the earth originated, include a lot of unstable radionuclides, as a result of which they undergo radioactive decay that causes them to emit energy as a form of terrestrial radiation. Humans are seriously impacted by terrestrial gamma radiation; they are mostly exposed to it from the top 30 cm of the soil. This work presents the statistical analysis of terrestrial gamma radiation dose rates with different soil types from the Southern region of Katsina State, Nigeria. The mean TGRD values range between 100 -143 nGy/h. Lixisols soil type recorded the highest TGRD with a mean value of 128.75 ± 2.99 nGy/h, while Arenosols have the lowest mean TGRD value of 105.67 ± 2.27 nGy/h. The average value of all the means (115.74 ± 2.20 nGy/h) was found to be almost twice the world average value of 59 nGy/h. An analysis of variance (ANOVA) test was performed to examine the TGRD values for the different soil types. The result revealed a non-significant difference in the values of TGRD between the various soil types. A one-way sample t-test was performed to compare the result of TGRD values with the world's average value of 59 nGy/h, which shows a statistically strong significant difference between the values and the world average value. The measured data may also be used to assess the radiation exposure of the general public, and safety standards and radiological guidelines could be developed.***
***Keywords: Terrestrial Gamma Radiation Dose, Radionuclides, Soil types, Katsina.***

## INTRODUCTION

The formation of soil, which contains living matter and provides sustenance for plants, is the result of the aggregation of natural bodies on the earth's surface. It is formed over time as a result of the interaction of natural and man-made processes with parent rock components (Johar et al. 2016). Known that high humidity and temperature on rocks cause extensive weathering, also the decay of primordial radionuclides such as $^{238}$U, $^{232}$Th, and $^{40}$K causes radioactivity in the soil's surface layers (Zorer 2019). The types of parent rocks from which the sediments emerge are linked to distinct quantities of terrestrial background radiation. Higher levels of radiation are found in igneous rocks containing dark-colored heavy minerals, whereas lower levels of radiation are found in sedimentary rocks. To document changes in the amount of radioactivity in soil owing to natural and artificial activities, it is necessary to determine the terrestrial gamma radiation dose distribution, which serves as a reference in estimating the health risk of a population (Obed et al. 2005).

Natural environmental radioactivity owing to gamma radiation appears at varying levels in soils of different regions across the world, which is primarily caused by geological and geographical factors (Chikasawa et al. 2001). Human beings are exposed outdoors to natural terrestrial radiation that originates predominantly from 30 cm top most of the soil (Tso and Leung, 2000). Therefore, gamma radiation emitted from naturally occurring radioisotopes, also called terrestrial radiation represents the main external source of irradiation to the human body (Tzortzis et al., 2003). Various researchers have proved the significance of baseline TGRD data gathered using in situ gamma-ray spectrometry in recent decades (Tzortzis et al., 2003; Abba et al., 2017; Bello et al., 2019; Garba et al., 2014; Saleh et al., 2013; Silas, 2017). It is important to note that offline γ-ray spectrometry with an HPGe detector produces data that is substantially more accurate, but it is a time-consuming, expensive, and labor-intensive method. However, in situ, γ-ray spectroscopy, which uses NaI(Tl) or HPGe detectors, provides a quick and affordable method for determining the radiation dosage to people. Since its development several decades ago, portable γ-ray spectrometry using a NaI(Tl) detector has been utilized for geological mapping, environmental investigations, and other applications due to its impressive benefits, including high efficiency, ease of operation, and maintenance (Beck, 1964).

Even though, several studies on terrestrial gamma radiation dose and associated health hazards in some areas of Katsina State have been conducted (Aku and Yusuf, 2015; Silas, 2017; Najib et al., 2016). However, due to several man-made and other natural activities (such as farming, mining activities, and erosion) in the study area, there is a need to study how the underlying different soil types influence the level of terrestrial gamma radiation dose in the study area. Therefore, the objective of this work is to obtain the most recent data on the level of terrestrial gamma radiation dose of the study area, and to use statistical tool to examine the contribution of the different soil types found in the study area towards the level of terrestrial gamma radiation dose.

## MATERIAL AND METHODS

### Materials

The following materials were used to carry out the study:

- A hand held global positioning system (GPS etrex 10), which was used in noting the location of each TGRD survey point.
- A portable gamma radiation survey meter (RDS 120) manufactured by mirion technologies, Finland, which was used in measuring the terrestrial gamma radiation doses (TGRD).
- Soil types maps; which was used in tracing and recording the location of each TGRD survey point.
- SPSS software package for data analysis
- ArcGIS software package, which was used in digitizing the soil maps and also aid in collecting the coordinate points traced at the field using GPS.

### Study area

The research location is located in the southern region of Katsina State, Nigeria, between 11° 10' N and 12° 23' N, and 06° 52' E and 07° 54' E. The area is bordered at the north by Dan-Musa local government area, at the east, by Kano State, at the west, by Zamfara State, and at the south, by Kaduna State. It is divided into 11 local government areas (Figure 1). Other than cultivation and farming, the soil in the study area is used for a variety of social and economic objectives, including building, mining, etc., both inside the study region and throughout the state. Based on the world reference base for soil resources (WRB), the study area has a total of 8 soil types which were grouped into 5 sets based on dominant identifiers, i.e., those soil forming factors that most clearly conditioned soil formation (FAO, 1998). The soil types in the study area, as well as the parent materials from which the soils were created, are listed in Table 1.

Table 1: Soil types of the study area and their mode of formation

| Label | FAO-UNESCO Legend | Formation | Parent Material |
|---|---|---|---|
| Set 3 | Arenosols | From parent material | Calcareous/Residual sandstone or siliceous rock |
| Set 4 | Fluvisols | By topography/physiography of the terrain | Lacutrine/Marine deposit (acidic soil) |
| | Leptosols | | Siliceous rock |
| | Regosols | | Unconsolidated finely grained material |
| Set 5 | Cambisols | By their limited age | Rocks of colluvial or alluvial deposits |
| Set 6 | Acrisols | By climate: (sub-humid) tropics | Acid rock weathering |
| | Lixisols | | Unconsolidated, strongly weathered material |
| Set 9 | Luvisols | By climate: (sub-humid) temperate regions | Unconsolidated material of glacial till, alluvial and colluvial deposits |

### Measurement of terrestrial gamma radiation dose (TGRD)

Measurements of radiation doses were conducted at sampling points, which were selected from the soil types map in Figure 1. Based on the soil type, the points were located with the aid of a Global Positioning System, Germin (etrex 10). The gamma radiation dose rate of each sampling point was measured using two standard radiation survey meters (RDS 120), which is used to measure gamma and x-rays within the dose range of 0.01 μSv – 10 Sv, the meter has a linear response to ionizing radiation between 0.4 keV and 1.2 MeV, the device is designed for a wide range of applications including the in-situ dose rate measurements in field conditions, in the nuclear industry, and for protection against radiological hazards by personnel in the working environment. The meters were held at a distance of 1 meter above the ground surface and readings were taken when the survey meter was stable with an average of four (4) readings (with 5-min intervals) at each point to minimize error. The meter readings were in micro roentgen per hour, and the mean TGRD readings were converted to $nGyh^{-1}$ using the recommended conversion factor of 1 $\mu R\ h^{-1}$ to 8.7 $nGyh^{-1}$.

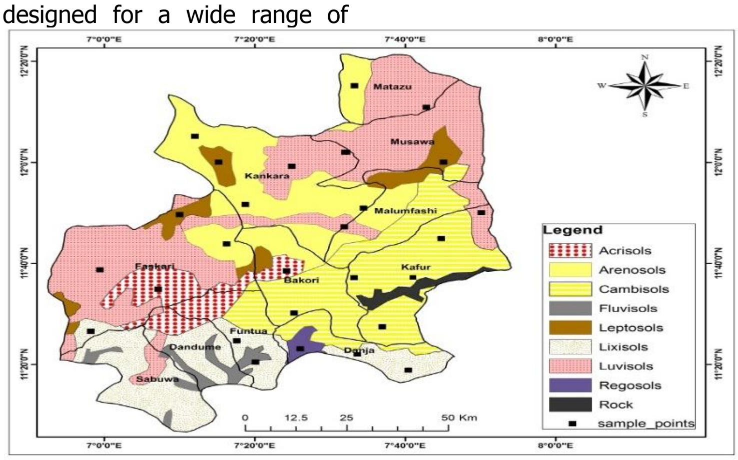


Figure 1: Soil types map of the study area (Centre for World Food Studies; 13th West & Central Africa Soil correlation, 1996)

**RESULTS AND DISCUSSION**

The measured TGRD of the sampling points for all the soil types ranges from 100 -143 nGy/h with a mean value of 115.74±2.20 nGy/h. Table 2 presents the results of the mean TGRD measurements for all the soil types indicating the mean, minimum, and maximum of all the values obtained, it also presents the standard deviation and the 95% confidence interval of the obtained means. The variation of the TGRD with the soil type is depicted in Figure 2 using a box plot, which indicates how the TGRD varies with the different soil types, the data shows a normal distribution as the mean is symmetrically distributed, and no outliers were observed in the obtained results of the soil types. Based on the measurements of TGRD for all the soil types, arenosols have the lowest mean TGRD of 105.67±2.27 nGy/h while lixisols were found to have the highest TGRD of 128.75±2.99 nGy/h, this is because lixisols which are known for accumulation of subsurface clay soil tend to have higher dose rate and arenosols which is a sandy textured soil was reported to have less absorbed dose rate as reported by Badawy (2009). All the measured values were found to be above the world mean value of 59 nGy/h as reported by UNSCEAR (2000).

Table 3 presents the result of the one-way analysis of variance (ANOVA) test, which was performed to examine the variation of the obtained TGRD among the soil types of the study area. The one-way ANOVA revealed there was no statistically significant difference in the mean of TGRD among the six (6) soil types ($F(5,21) = 2.62$, $p = 0.054$). These findings indicate that there was no statistically significant difference between the result of TGRD among the six (6) different soil types ($p = 0.054$).

A one-sample t-test was also carried out to evaluate whether there was a significant difference between the mean TGRD from different soil types compared to the world average value of 59 nGy/h. The result from the one sample t-test indicates that the mean TGRD from different soil types with a degrees of freedom (df = 26) is (M = 115.74, SD = 11.42) which is statistically more significant ($p < .001$, 55.74) than the world average value of TGRD, $t(26) = 25.36$, $p < .001$. The result is presented in Table 4.

Table 2: Descriptive statistics of the mean TGRD based on soil types

| Soil types | Sample size (N) | Mean (nGy/h) | Std. Deviation | Std. Error | 95% Confidence Interval for Mean | | Min. (nGy/h) | Max. (nGy/h) |
|---|---|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound | | |
| Acrisols | 4 | 113.75 | 2.10 | 1.05 | 110.41 | 117.09 | 111.67 | 116.67 |
| Arenosols | 5 | 105.67 | 5.08 | 2.27 | 99.36 | 111.98 | 100.00 | 111.67 |
| Cambisols | 5 | 119.33 | 11.22 | 5.02 | 105.40 | 133.26 | 108.33 | 136.67 |
| Leptosols | 3 | 112.22 | 5.09 | 2.94 | 99.57 | 124.87 | 106.67 | 116.67 |
| Lixisols | 4 | 128.75 | 5.99 | 2.99 | 119.22 | 138.28 | 123.33 | 136.67 |
| Luvisols | 6 | 115.56 | 16.18 | 6.61 | 98.57 | 132.54 | 100.00 | 143.33 |
| Total | 27 | 115.74 | 11.42 | 2.20 | 111.22 | 120.26 | 100.00 | 143.33 |

Table 3: Analysis of Variance (ANOVA) for TGRD based on soil types

| Sampling type | Parameters | Sum of Squares (SS) | Degrees of freedom (df) | Mean Square (MS) | F | Sig. |
|---|---|---|---|---|---|---|
| Soil types | Between Groups | 1302.13 | 5 | 260.43 | 2.62 | .054 |
| | Within Groups | 2088.61 | 21 | 99.46 | | |
| | Total | 3390.74 | 26 | | | |

Table 4: One sample t-test for TGRD based on soil types

| | Test Value = 59 nGy/h | | | | | |
|---|---|---|---|---|---|---|
| | t | Degrees of freedom (df) | Sig. (2-tailed) | Mean Difference | 95% Confidence Interval of the Difference | |
| | | | | | Lower | Upper |
| Terrestrial gamma radiation dose | 25.36 | 26 | .000 | 55.74 | 51.22 | 60.26 |

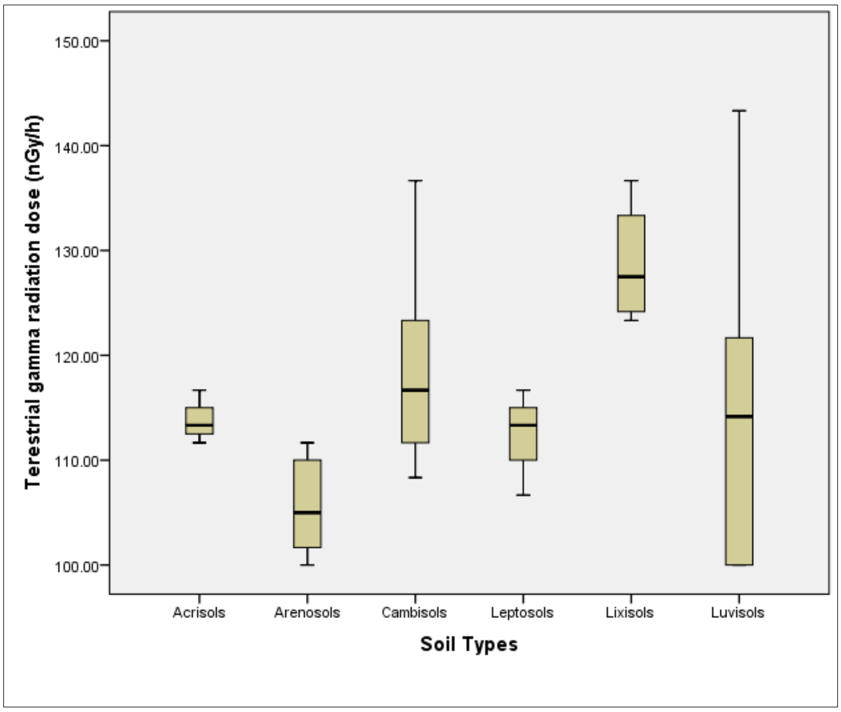


Figure 2: Box plot of the mean of TGRD based on soil types

The obtained mean results of the TGRD from this study was compared with that of other places reported in the literature, the comparison is presented in Table 5. It is shown that the results, though higher than the results in some parts of Nigeria and almost twice the world TGRD mean value, it is lower than the results reported in some parts of Nigeria, especially Jos, Plateau State.

Table 5: Comparison of TGRD rates in some parts of Nigeria

| Location | TGRD ($nGy\ h^{-1}$) | | Reference |
|---|---|---|---|
| | Mean | Range | |
| Katsina South (Nigeria) | 115.74 | 100 -143 | This Study |
| Eastern Obolo, Akwa Ibom | 20.45 | --- | (Alias, Hamzah, Saat, Omar, & Wood, 2008) |
| Eket, Akwa Ibom | 18.26 | --- | (Alias et al., 2008) |
| Ibeno, Akwa Ibom | 25.99 | --- | (Alias et al., 2008) |
| Uyo, Akwa Ibom | 20.27 | --- | (Alias et al., 2008) |
| Jos, Plateau | 204 | 11 – 714 | (Abba & Abdulsalam, 2017) |

## CONCLUSION

The study presents a baseline data on terrestrial gamma radiation dose (TGRD) rates and their distribution over the different soil types in Katsina South, Nigeria. The data were obtained by an in-situ measurement using a handheld RADOS (RDS-120) radiation survey meter. The mean values of the measured TGRD for all the sampling points were found to have a mean of 115.74 nGy/h which ranges between 100 -143 nGy/h, it is within the typical TGRD in air variability range of 10 - 200 nGy/h as reported by UNSCEAR, (2008), the results are higher than those reported from some parts of Nigeria but less than the mean value reported for Jos, Plateau State by Abba & Abdulsalam, 2017, This might be due to higher agricultural activities in the study area, which include application of fertilizer and manure. A one-way ANOVA test revealed there was no statistically significant difference between the result of TGRD among the six (6) different soil types ($p = 0.054$), this implies that the level of TGRD measured from the study area for the different soil types exhibit similar result for all the six (6) soil types throughout the study area. Also, the one-sample t-test indicates that the obtained results of mean TGRD was significantly more than the world average value of 59 nGy/h ($p < .001$), the result from this test signifies that the measured TGRD from the current study is significantly higher than the world mean value of TGRD in air. In addition to other factors that can cause elevated level of TGRD in air, this result also implies that the different soil types in the study area have some influence on the level of TGRD in the study area.

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