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# MAPPING OF NATURAL GAMMA RADIATION (NGR) DOSE RATE DISTRIBUTION AROUND GIDAN-KWANO AREA, MINNA, NORTH-CENTRAL NIGERIA

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Abstract: An in-situ measurement of the background radiation level was carried out in Gidan-Kwano, Minna, Niger state with an objective to establish a reference data record on the levels and distribution of natural background gamma radiation (NGR). The measurement was carried out using a portable calibrated NaI(Tl) scintillation survey meter. A total of 153 points were surveyed across the study area for background environmental radiation. The results obtained, varied significantly due to geological features of the study area. NGR dose rates values ranged between 87 – 252.3 nGyh$^{-1}$ with overall mean value of 136.75 nGyh$^{-1}$. This is more than twice higher than the reported world average value of 59 nGyh$^{-1}$. However, the average annual effective dose obtained from this study is 0.17 mSv/annum, which is less than the recommended limit of 1 mSv/annum by International Commission on Radiation Protection [ICRP] for non-occupational population exposure. An isodose map for the distribution and exposure rate due to natural sources radiation for the study area was also plotted using ArcGIS software.

**Keywords:** Natural gamma radiation, dose rate, mean dose rate, isodose map

## Introduction

Natural background gamma radiation exists all around us. Men are continuously exposed to these radiations due to terrestrial and cosmic sources (Taskin *et al*., 2009). According to United Nations Scientific Committee on the Effects of Atomic Radiation report (UNSCEAR), the greatest contribution to mankind's exposure comes from natural background radiation, and the global average annual effective dose is 2.4 mSv. An assessment of gamma radiation from natural sources is of particular importance (Kurnaz, 2013; Faanu *et al*., 2011; Ramli *et al*., 2009; Gbenu *et al*., 2020a; 2020b; Oladejo *et al*., 2020).

Radioactivity levels in environment vary greatly, depending on soil type and its mineral contents (Ramli *et al*., 2009; Garba *et al*., 2014; Saleh *et al*., 2013). Uranium, thorium and potassium are all present in the Earth's crust in concentrations of 2 – 4 and 8 – 12 ppm and around 2.5 wt%, respectively. In rocks, they are present in the form of a number of minerals (Mares, 1984). Radiation measurements and potential risks of exposure to low-dose natural radioactivity have been of interest in recent times (Kapdan *et al*., 2011; Isik *et al*., 2012; Khan *et al*., 2012; Gabdo *et al*., 2015; Saleh *et al*., 2015).

This study is aimed at producing a radiological map of the study area – Gidan-Kwano area, Minna, Niger state for the first time. This is essential due to the recent activities of local miners in the study area, and most especially now that the Federal Government of Nigeria has granted the Federal University of Technology, Minna a mining license. More so, the population of the study area has increased tremendously in recent times which is as a result of two major factors; the presence of Federal University of Technology, Minna, with its increasing enrolment over time. Hence, the data obtained will serve as background radiation level baseline to monitor the mining activity of the study area.

## Materials and Methods

### *Study area*

The study area – Gidan-Kwano area, is located on latitude 9° 30′ N and 9° 34′ N and longitude 6° 24′ E and 6° 28′ E. The study area was gridded into a total of 153 points and background environmental radiation survey was carried out at each point shown in Fig. 1. The study area is in Niger State, which is covered by two major rock formations; the sedimentary and basement complex rocks. The sedimentary rocks to the south are characterized by sand stones and alluvial deposits, particularly along the Niger valley and in most parts of Borgu, Bida, Agaie, Lapai, Mokwa, Lavun, Gbako and Wushishi Local Government Areas. This subarea also contains the extensive flood plains of the River Niger and this has made the state to be one of the largest and most fertile agricultural lands in the country. To the north is the basement complex, characterized by granitic outcrops or inselbergs which can be found in the vast topography of rolling landscape. Such inselbergs dominate the landscape in Rafi, Shiroro, Minna, Mariga and Gurara (Ajibade, 1976). Fig. 2 gives the geological formations of the study area.

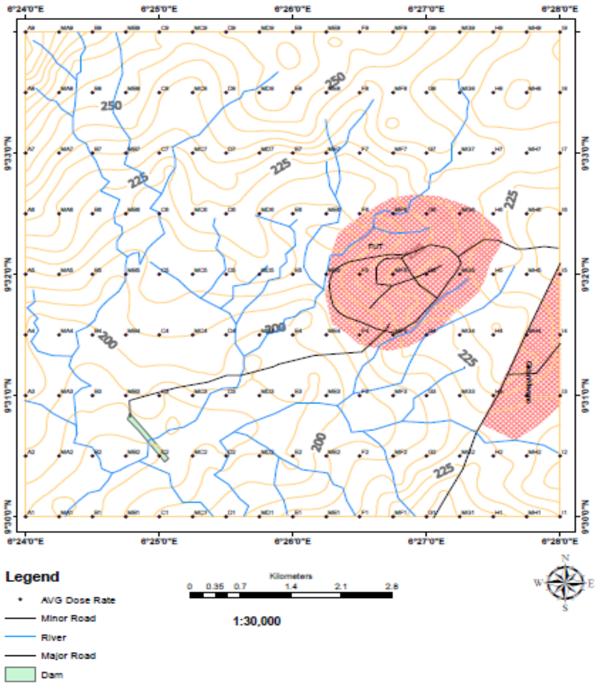

**Fig. 1: Survey points of the study area**

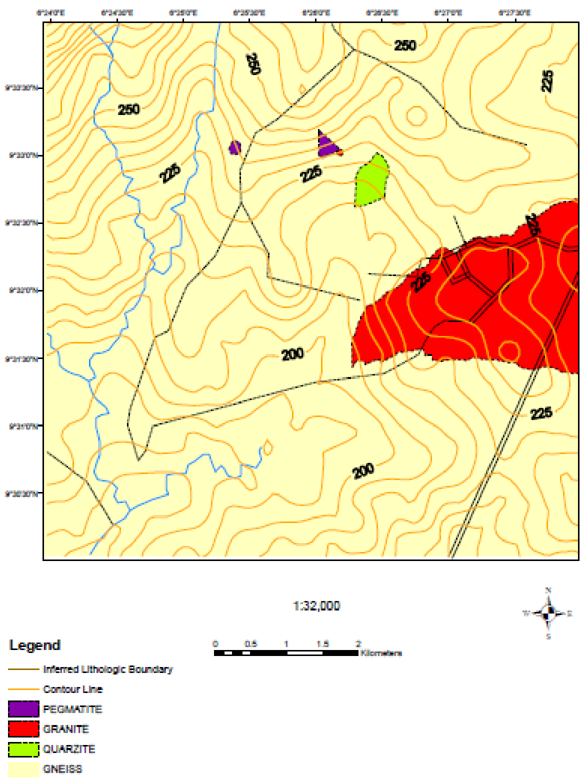

**Fig. 2: Geological formations of the study area**

### *NGR dose rates measurement*

An in situ NGR dose rates measurement was conducted using a portable calibrated NaI(Tl) scintillation survey meter (Inspector Alert$^{TM}$ Nuclear Radiation Monitor, Serial Number – 35440) manufactured by International Medcom, Inc., USA. The meter uses (2.54 X 2.54 $cm^2$) sodium iodide (NaI) crystal doped with thallium (Tl) as detector. Measurements were conducted randomly at 1m above soil surface at 153 different locations. Geographical coordinates of the measurement locations were recorded by Global Positioning System (GPS), Garmin eTrex 10 model. The meter displays dose rate reading in $\mu Rh^{-1}$ which was subsequently converted to $nGyh^{-1}$ using a conversion factor 1 $\mu Rh^{-1} \sim 8.7\ nGyh^{-1}$ (Saleh *et al.*, 2013a). The relatively linear energy response of the detector between the gamma ray energies of 0.08 and 1.2 meV makes its excellent for field measurements (Knoll, 2010). Fig. 1 shows the measurement locations. To minimize errors, dose rate readings were recorded when the meter pointer was stable, and at least three set of readings were taken at a given point within the domain of the geological formations and soil types. Thereafter, the mean value for each location was computed from the set of the readings. To measure the actual NGR dose rates, measurements were made in an undisturbed open field and far away from mines and mining installations or facilities.

### *Plotting of isodose map*

The data set on NGR dose rate measurements plus the coordinates for all data points were used in plotting an isodose map using ArcGIS version 10.3 – a mapping and spatial analysis software. The isodose map represents the distribution of NGR and exposure rates of the study area. Kriging technique was adopted for the plotting (Aziz Saleh *et al.*, 2014; Gerrard, 2000). This technique uses decreasing weight for the interpolation based on a semivariogram of survey points (Apriantoro, 2008). The datum used for the GPS was set up to the world geodetic system (WGS) 1984 and synchronized with coordinates of survey points.

## Results and Discussion

The obtained NGR dose rates at each 153 points of the study area with their corresponding coordinates are given in Table 1 and the summary of the obtained dose rates is given in Table 2. The values were in the range of 87.0 – 252.3 $nGyh^{-1}$, with a mean value of 136.75 $nGyh^{-1}$. The obtained mean value is more than twice the world value of 59 $nGyh^{-1}$ reported by UNSCEAR (2000).

**Table 1: Summary of the dose rate in soil samples**

| S/N | Longitudes | Latitudes | AVG(nGy/h) |
|---|---|---|---|
| 1 | 6 24’ 0’’E | 9 300 N | 121.80 |
| 2 | $6^0$ 24 15 E | 9 30 0 N | 113.10 |
| 3 | $6^0$ 24 30 E | 9 30 0 N | 182.70 |
| 4 | 6 24 45 E | 9 30 0 N | 113.10 |
| 5 | 6 25 0 E | 9 30 0 N | 139.20 |
| 6 | 6 25 15 E | 9 30 0 N | 113.10 |
| 7 | 6 25 30 E | 9 30 0 N | 121.80 |
| 8 | 6 25 45 E | 9 30 0 N | 113.10 |
| 9 | 6 26 0 E | 9 30 0 N | 130.50 |
| 10 | 6 26 15 E | 9 30 0 N | 130.50 |
| 11 | 6 26 30 E | 9 30 0 N | 104.40 |
| 12 | 6 26 45 E | 9 30 0 N | 121.80 |
| 13 | 6 27 0 E | 9 30 0 N | 121.80 |
| 14 | 6 27 15 E | 9 30 0 N | 121.80 |
| 15 | 6 27 30 E | 9 30 0 N | 130.50 |
| 16 | 6 27 45 E | 9 30 0 N | 113.10 |
| 17 | 6 28 0 E | 9 30 0 N | 156.60 |
| 18 | 6 24’ 0’’E | 9 30 30 N | 130.50 |
| 19 | $6^0$ 24 15 E | 9 30 30 N | 113.10 |
| 20 | $6^0$ 24 30 E | 9 30 30 N | 139.20 |
| 21 | 6 24 45 E | 9 30 30 N | 156.60 |
| 22 | 6 25 0 E | 9 30 30 N | 130.50 |
| 23 | 6 25 15 E | 9 30 30 N | 104.40 |
| 24 | 6 25 30 E | 9 30 30 N | 113.10 |
| 25 | 6 25 45 E | 9 30 30 N | 139.20 |
| 26 | 6 26 0 E | 9 30 30 N | 174.00 |
| 27 | 6 26 15 E | 9 30 30 N | 121.80 |
| 28 | 6 26 30 E | 9 30 30 N | 147.90 |
| 29 | 6 26 45 E | 9 30 30 N | 147.90 |
| 30 | 6 27 0 E | 9 30 30 N | 121.80 |
| 31 | 6 27 15 E | 9 30 30 N | 113.10 |
| 32 | 6 27 30 E | 9 30 30 N | 130.50 |
| 33 | 6 27 45 E | 9 30 30 N | 104.40 |
| 34 | 6 28 0 E | 9 30 30 N | 121.80 |
| 35 | 6 24’ 0’’E | 9 310 N | 121.80 |
| 36 | $6^0$ 24 15 E | 9 31 0 N | 182.70 |
| 37 | $6^0$ 24 30 E | 9 31 0 N | 191.40 |
| 38 | 6 24 45 E | 9 31 0 N | 147.90 |
| 39 | 6 25 0 E | 9 31 0 N | 139.20 |
| 40 | 6 25 15 E | 9 31 0 N | 147.90 |
| 41 | 6 25 30 E | 9 31 0 N | 113.10 |
| 42 | 6 25 45 E | 9 31 0 N | 139.20 |
| 43 | 6 26 0 E | 9 31 0 N | 113.10 |
| 44 | 6 26 15 E | 9 31 0 N | 104.40 |
| 45 | 6 26 30 E | 9 31 0 N | 0.00 |
| 46 | 6 26 45 E | 9 31 0 N | 121.80 |
| 47 | 6 27 0 E | 9 31 0 N | 0.00 |
| 48 | 6 27 15 E | 9 31 0 N | 147.90 |
| 49 | 6 27 30 E | 9 31 0 N | 121.80 |
| 50 | 6 27 45 E | 9 31 0 N | 130.50 |
| 51 | 6 28 0 E | 9 31 0 N | 191.40 |
| 52 | 6 24 0 E | 9 31 30 N | 182.70 |
| 53 | $6^0$ 24 15 E | 9 31 30 N | 139.20 |
| 54 | $6^0$ 24 30 E | 9 31 30 N | 147.90 |
| 55 | 6 24 45 E | 9 31 30 N | 121.80 |
| 56 | 6 25 0 E | 9 31 30 N | 156.60 |
| 57 | 6 25 15 E | 9 31 30 N | 130.50 |
| 58 | 6 25 30 E | 9 31 30 N | 147.90 |

| | | | |
|---|---|---|---|
| 59 | 6 25 45 E | 9 31 30 N | 104.40 |
| 60 | 6 26 0 E | 9 31 30 N | 139.20 |
| 61 | 6 26 15 E | 9 31 30 N | 113.10 |
| 62 | 6 26 30 E | 9 31 30 N | 130.50 |
| 63 | 6 26 45 E | 9 31 30 N | 217.50 |
| 64 | 6 27 0 E | 9 31 30 N | 217.50 |
| 65 | 6 27 15 E | 9 31 30 N | 104.40 |
| 66 | 6 27 30 E | 9 31 30 N | 130.50 |
| 67 | 6 27 45 E | 9 31 30 N | 156.60 |
| 68 | 6 28 0 E | 9 31 30 N | 200.10 |
| 69 | 6 24’ 0’’E | 9 320 N | 156.60 |
| 70 | $6^0$ 24 15 E | 9 32 0 N | 121.80 |
| 71 | $6^0$ 24 30 E | 9 32 0 N | 104.40 |
| 72 | 6 24 45 E | 9 32 0 N | 113.10 |
| 73 | 6 25 0 E | 9 32 0 N | 121.80 |
| 74 | 6 25 15 E | 9 32 0 N | 121.80 |
| 75 | 6 25 30 E | 9 32 0 N | 156.60 |
| 76 | 6 25 45 E | 9 32 0 N | 147.90 |
| 77 | 6 26 0 E | 9 32 0 N | 104.40 |
| 78 | 6 26 15 E | 9 32 0 N | 121.80 |
| 79 | 6 26 30 E | 9 32 0 N | 156.60 |
| 80 | 6 26 45 E | 9 32 0 N | 139.20 |
| 81 | 6 27 0 E | 9 32 0 N | 156.60 |
| 82 | 6 27 15 E | 9 32 0 N | 121.80 |
| 83 | 6 27 30 E | 9 32 0 N | 182.70 |
| 84 | 6 27 45 E | 9 32 0 N | 139.20 |
| 85 | 6 28 0 E | 9 32 0 N | 147.90 |
| 86 | 6 24 0E | 9 32 30 N | 252.30 |
| 87 | $6^0$ 24 15 E | 9 32 30 N | 182.70 |
| 88 | $6^0$ 24 30 E | 9 32 30 N | 130.50 |
| 89 | 6 24 45 E | 9 32 30 N | 121.80 |
| 90 | 6 25 0 E | 9 32 30 N | 174.00 |
| 91 | 6 25 15 E | 9 32 30 N | 130.50 |
| 92 | 6 25 30 E | 9 32 30 N | 139.20 |
| 93 | 6 25 45 E | 9 32 30 N | 130.50 |
| 94 | 6 26 0 E | 9 32 30 N | 165.30 |
| 95 | 6 26 15 E | 9 32 30 N | 139.20 |
| 96 | 6 26 30 E | 9 32 30 N | 121.80 |
| 97 | 6 26 45 E | 9 32 30 N | 95.70 |
| 98 | 6 27 0 E | 9 32 30 N | 147.90 |
| 99 | 6 27 15 E | 9 32 30 N | 139.20 |
| 100 | 6 27 30 E | 9 32 30 N | 130.50 |
| 101 | 6 27 45 E | 9 32 30 N | 147.90 |
| 102 | 6 28 0 E | 9 32 30 N | 95.70 |
| 103 | 6 24’ 0’’E | 9 330 N | 147.90 |
| 104 | $6^0$ 24 15 E | 9 33 0 N | 147.90 |
| 105 | $6^0$ 24 30 E | 9 33 0 N | 113.10 |
| 106 | 6 24 45 E | 9 33 0 N | 147.90 |
| 107 | 6 25 0 E | 9 33 0 N | 182.70 |
| 108 | 6 25 15 E | 9 33 0 N | 139.20 |
| 109 | 6 25 30 E | 9 33 0 N | 156.60 |
| 110 | 6 25 45 E | 9 33 0 N | 174.00 |
| 111 | 6 26 0 E | 9 33 0 N | 147.90 |
| 112 | 6 26 15 E | 9 33 0 N | 0.00 |
| 113 | 6 26 30 E | 9 33 0 N | 174.00 |
| 114 | 6 26 45 E | 9 33 0 N | 165.30 |
| 115 | 6 27 0 E | 9 33 0 N | 0.00 |
| 116 | 6 27 15 E | 9 33 0 N | 0.00 |
| 117 | 6 27 30 E | 9 33 0 N | 121.80 |
| 118 | 6 27 45 E | 9 33 0 N | 113.10 |
| 119 | 6 28 0 E | 9 33 0 N | 139.20 |
| 120 | 6 24’ 0’’E | 9 33 30 N | 130.50 |
| 121 | $6^0$ 24 15 E | 9 33 30 N | 139.20 |
| 122 | $6^0$ 24 30 E | 9 33 30 N | 147.90 |
| 123 | 6 24 45 E | 9 33 30 N | 200.10 |
| 124 | 6 25 0 E | 9 33 30 N | 174.00 |
| 125 | 6 25 15 E | 9 33 30 N | 147.90 |
| 126 | 6 25 30 E | 9 33 30 N | 191.40 |
| 127 | 6 25 45 E | 9 33 30 N | 113.10 |
| 128 | 6 26 0 E | 9 33 30 N | 87.00 |
| 129 | 6 26 15 E | 9 33 30 N | 113.10 |
| 130 | 6 26 30 E | 9 33 30 N | 156.60 |
| 131 | 6 26 45 E | 9 33 30 N | 147.90 |
| 132 | 6 27 0 E | 9 33 30 N | 130.50 |
| 133 | 6 27 15 E | 9 33 30 N | 165.30 |
| 134 | 6 27 30 E | 9 33 30 N | 191.40 |
| 135 | 6 27 45 E | 9 33 30 N | 0.00 |
| 136 | 6 28 0 E | 9 33 30 N | 121.80 |
| 137 | 6 24’ 0’’E | 9 340 N | 165.30 |
| 138 | $6^0$ 24 15 E | 9 34 0 N | 191.40 |
| 139 | $6^0$ 24 30 E | 9 34 0 N | 165.30 |
| 140 | 6 24 45 E | 9 34 0 N | 156.60 |
| 141 | 6 25 0 E | 9 34 0 N | 147.90 |
| 142 | 6 25 15 E | 9 34 0 N | 208.80 |
| 143 | 6 25 30 E | 9 34 0 N | 165.30 |
| 144 | 6 25 45 E | 9 34 0 N | 165.30 |
| 145 | 6 26 0 E | 9 34 0 N | 147.90 |
| 146 | 6 26 15 E | 9 34 0 N | 182.70 |
| 147 | 6 26 30 E | 9 34 0 N | 156.60 |
| 148 | 6 26 45 E | 9 34 0 N | 147.90 |
| 149 | 6 27 0 E | 9 34 0 N | 139.20 |
| 150 | 6 27 15 E | 9 34 0 N | 191.40 |
| 151 | 6 27 30 E | 9 34 0 N | 165.30 |
| 152 | 6 27 45 E | 9 34 0 N | 113.10 |
| 153 | 6 28 0 E | 9 34 0 N | 113.10 |

**Table 2: Summary of the basic statistics for external gamma dose rates**

| Statistics | Dose rate (nGy/h) |
|---|---|
| Mean | 136.75 |
| Range | 87.0 – 252.3 |
| SE | 3.18 |
| SD | 39.32 |
| Median | 139.20 |
| Mode | 147.90 |
| World average | 59 |

**Table 3: Mean dose rate for this study compared to other countries of the world**

| S/N | Country/Region | Dose rate (nGy/h) | References |
|---|---|---|---|
| 1 | Southwest, Nigeria | 232 | Jibiri *et al.* (2016) |
| 2 | Ghana | 741 | Faanu *et al.* (2016) |
| 3 | Jos Plateau | 250 | Abba *et al.* (2017) |
| 4 | Minna | 154 | Olarinoye *et al.* (2010) |
| 5 | Malaysia | 209 | Nuraddeen *et al.* (2015) |
| 6 | Portugal | 84 | UNSCEAR (2000) |
| 7 | USA | 47 | UNSCEAR (2000) |
| 8 | India | 56 | UNSCEAR (2000) |
| 9 | Iran | 105 | Baykara and Dogru (2009) |
| 10 | Brazil | 125 | Freitas and Alencar (2004) |
| 11 | Spain | 76 | UNSCEAR (1988) |
| 12 | World average | 59 | UNSCEAR (2000) |
| 13 | Gidan-Kwano, Minna | 136.75 | This study |

The highest dose rate was recorded due to the soil type underlain by granitic rock formation while the lowest was recorded because of the sandstone, clay and shale formations which were underlain by sedimentary rocks. Soils derived from granitic parent material are known to contribute to higher dose rates (UNSCEAR, 2000) compared to soils developed as a result of decomposition of organic matter such as peat, muck and shale (Sanusi *et al.* 2014). This is because; the minerals that carry U and Th are generally associated with felsic intrusive rocks, particularly with younger granites compared to ultramafic and volcanic rocks (Amadi *et al.*, 2012). The results of this study are in general agreement with similar studies conducted by Ramli *et al*. (2009), Saleh *et al*. (2013a and b), Lee (2009), and Garba *et al*., (2015) who reported dose rates of higher values for soils of igneous origin. Dose rate of as low as 8.7 nGyh$^{-1}$ was reported by Tzortzis *et al*. (2004) for the soil of sedimentary rocks in Cyprus. The total mean dose rate of the surveyed area is found to be more than twice that of the world average, and found to be higher than that of other places (Olarinoye *et al*., 2010; Jibiri *et al*., 2016; Faanu *et al*., 2016; Abba *et al*., 2017) as shown Table 3. Figs. 3 and 4 show the isodose map of the study area and the frequency distribution curve for dose rates, respectively. The NGR distribution of the study area is determined majorly by the basement rocks and human activities.

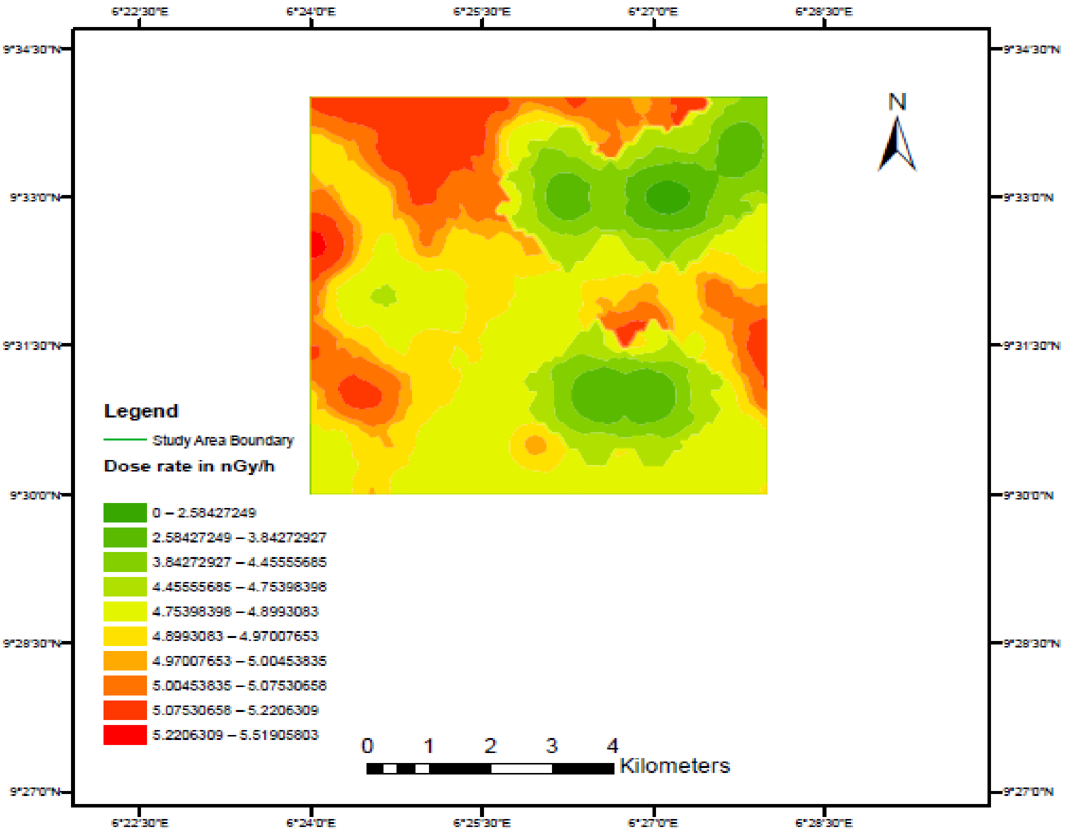

**Fig. 3: Isodose map of the NGR dose rates**

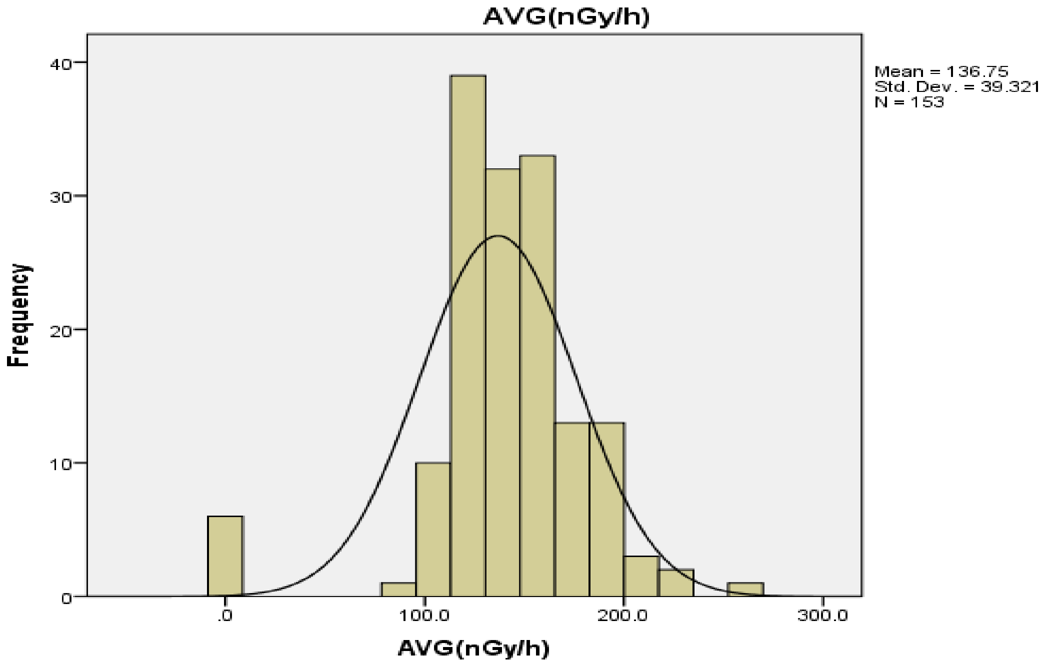

**Fig. 4: Frequency distribution curve for dose rates**

### *Estimation of annual effective dose (AED)*

The obtained mean dose rate was used to compute the mean indoor and outdoor annual effective doses due to exposure to natural sources of background gamma radiation. The parameters were estimated by assuming the conversion coefficient for the absorbed dose in air to effective dose of 0.7 Sv Gy-1, and the indoor and outdoor occupancy factors of 0.8 and 0.2, respectively, as recommended by UNSCEAR (2000). The indoor and outdoor annual effective dose equivalent was estimated using Equation 1 and 2, respectively.

$$AED_{in}\ (mSv/y) = \text{mean dose rate } (nGy/h) * 24(h) * 365(days) * 0.8 * 0.7 * 10^{-6} \qquad (1)$$

$$AED_{ext}(mSv/y) = \text{mean dose rate } (nGy/h) * 24(h) * 365(days) * 0.2 * 0.7 * 10^{-6} \qquad (2)$$

Assuming the population in the study area spend 20% of their day in this area (UNSCEAR, 2000), the obtained annual effective dose is 0.17 mSv/annum. The obtained value is lower than the recommended limit of 1 mSv/annum by International Commission on Radiation Protection (ICRP, 1990).

## Conclusion

The high background radiation observed in this study area could be attributed only to natural sources (cosmic and terrestrial). The geology of the town also suggests that the soil in Minna town has a large deposit of granite. It is well known that granites contain high concentrations of uranium, thorium and potassium (Ivanovich and Harmon, 1982). The overall mean value for this study is computed to be 136.75 $nGyh^{-1}$ with a standard deviation of 39.32 $nGyh^{-1}$. This value falls within the highest range of those measured at worldwide scale by other authors and, more specifically, is by a factor of more than twice times higher than the reported world average values of 59 $nGyh^{-1}$ in the UNSCEAR (2000) report. The mean indoor and outdoor annual effective doses for the public were estimated to be 0.67 and 0.17 mSv/y, respectively, which are less than the dose limit recommended by the ICRP. The isodose map for the distribution NGR and exposure rate for the study area was also plotted using ArcGIS software. Thus, there is a need for a comprehensive radiological study in the areas covered by this work to ascertain the radionuclide responsible for the elevated gamma dose rates.

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## Conflict of Interest

The authors declare that there is no conflict of interest related to this study.

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