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Evaluation of Gamma Radiation Dose Level in Mining Sites of Riruwai, Kano, Nigeria

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Abstract: *Some radioelements are natural with redistribution related to human activities like mining. Human beings are constantly associated with these radioelements through water and food intake and may be exposed to background natural radiation from terrestrial and cosmic sources. Among all types of radiation, gamma rays are the most penetrating radiation that emanates from natural and artificial sources. External exposure to gamma radiation varies from one location to another, depending on the geological composition, and elemental content (especially those of U, Th and K in rocks of a particular region). In this study, gamma radiations around mining areas in Riruwai were measured using RadEye Portable Radiation Detector. Gamma dose measurements were taken from 40 sampling locations and at 1 m above the soil surface. Geographical coordinates of the locations were taken using a Global Positioning System (GPS). The analyses show that the gamma radiation dose level attended a mean value of 749 nGy/hr which is thirteen times greater than the maximum permissible value (57-59 nGy/hr) recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). The mean indoor and outdoor annual effective doses (AED) were 0.91 and 3.65mSv/yr, which are about three and four times more than their respective world average values of 0.3 mSv/y and 1mSv/y respectively. The Excess Lifetime Cancer Risk (ELCR) factors were 2.51 $\times 10^{-3}$ and 10.5 $\times 10^{-3}$ for indoor and outdoor respectively and these correspond to a nine-fold increase of their world average values of 0.29×10^{-3} and 1.16×10^{-3} as prescribed by the UNSCEAR. The computed data indicated that miners and the public residing close to the mining zone may be at risk and there is a need for an urgent remediation process. The results of this study can provide valuable information on radiological risk which could be used for radiation safety and protection and in the utilization of the soil in the region for agriculture and domestic use. It also contributes to baseline radiological data that could be used by the policymakers and for future studies.*

Keywords: *Absorbed dose, cancer, gamma radiation, mining areas, radiological hazards*

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1.0 Introduction

Natural radiation has always been part of our environment. Its main components are cosmic and cosmogenic radiation, gamma radiation from radionuclides in rocks and soil, and also radiation from the radioelements in the air and water (Saied *et al*. 2016). These radioelements have redistribution related to human activities indicating that human beings are constantly associated with these radioelements through water and food intake, and they are also exposed to background

Gamma Radiation Dose Level (GRDL) from terrestrial and cosmic sources (Abba *et al.* 2018). There exists a strong relationship between the geological formation and the Natural Gamma Radiation (NGR) of a given environment. Radiological studies from younger granite geological formations which are characterized by composed coarse-grained biotite micrograntes and some basic rocks are recorded to have a higher GRDL above the maximum permissible value (MPV), especially if mining activities do take place in the region. Previous radiological studies conducted on some younger granite indicate higher GRDL and radiological index parameters above their world average values. The relevant radiological studies on granite formations are reported elsewhere (Faanu *et al*. 2016, Abba *et al*. 2017, Adukpo *et al.* 2016, Abba *et al*. 2017, Mouandza *et al.* 2018, Usikalu *et al.* 2019, Adabanija *et al*. 2020, Akpanowo *et al.* 2020, Aliyu *et al.* 2020). Among other types of radiation, gamma rays are the most penetrating radiation from natural and artificial sources and can easily be detected and measured.

Riruwai is one of the fifty-two separate younger granite ring complexes in Nigeria and mining activities have been taking place in the area for quite a long time (Olasehinde *et al.* 2012). Some of the mining sites are located close to settlements and farmlands where agricultural and other human activities are being carried out. Artisanal mining and processing of Tin, Columbite, Lead and other solid minerals have been taking place for some decades at Riruwai town of Kano State. These activities have led to the deposition of a large quantity of tailings heaps that were sporadically spread over large areas. The dwellers reworked these tailings, used them for building materials, and farmed the lands. A major concern is that the exposed natural radionuclides may gain access to man via external irradiation by gamma rays and internal irradiation by inhalation of radon gas from ore dust, and by ingestion of radioactively contaminated food. Although, several studies have reported vast radiological data from geological formations similar to that of Riruwai mainly on Jos Plateau, very little work has been done on Riruwai mining sites. In the light of the foregoing explanation, it is therefore important to undertake the radiological risk assessment of the Riruwai mining sites to gain an idea of the radiological information that could be used to quantify the potential radiological danger to the members of the public and environment. The background radiation dose measurement would contribute to baseline data for the area that could be used for the feature studies and in the control of radiation hazards through the establishment of laws for the best practice.

The main objective of the present study is to measure the gamma radiation dose level in Tin and Columbite mining areas of Riruwai town of Kano State, Nigeria to quantify the potential radiological danger to the dwellers of the study area and its surroundings.

2.0 Materials and methods

2.1 Study area

Riruwai is in Doguwa Local Government Area of Kano State and is located about l40 km south of Kano. It is bounded by latitude 10^{o} 43′ 97″ – 10^{o} 45′ 01″ N and longitude 8^{o} 43′ 03″ – 8^{o} 47′ 39″. The settlement covers an area of 129 km^2 and has an estimated population of 151,181 (NPC 2006). The town has an underlay younger Granite ring complexes, making it suitable for mining activity. The vegetation of the zone is dominated by the Sudan Savannah, which is characterized by shrubs in the relatively flat land to light forest in the valleys and around the hills. The town is characterized by two main climatic seasons, rainy and dry seasons (Ibeneme *et al*. 2018). Fig. 1 shows the location of the study area extracted from the map of Kano State (Badamasi *et al*., 2021).

2.2 Measurement of GRDL

An in-situ measurement of GRDL was conducted using a portable NaI (Tl) scintillation survey meter (RadEye PRD) manufactured by Thermo Fisher Scientific company. Measurements were carried out randomly at 1 m above the soil surface at 40 various locations. Geographical coordinates of the locations were taken using a Global Positioning System (GPS). Errors were reduced by taking the dose rate reading when the meter counter was stable, readings were taken three times in each location and averages were taken. After which the mean value for each location was taken from the set of the readings.

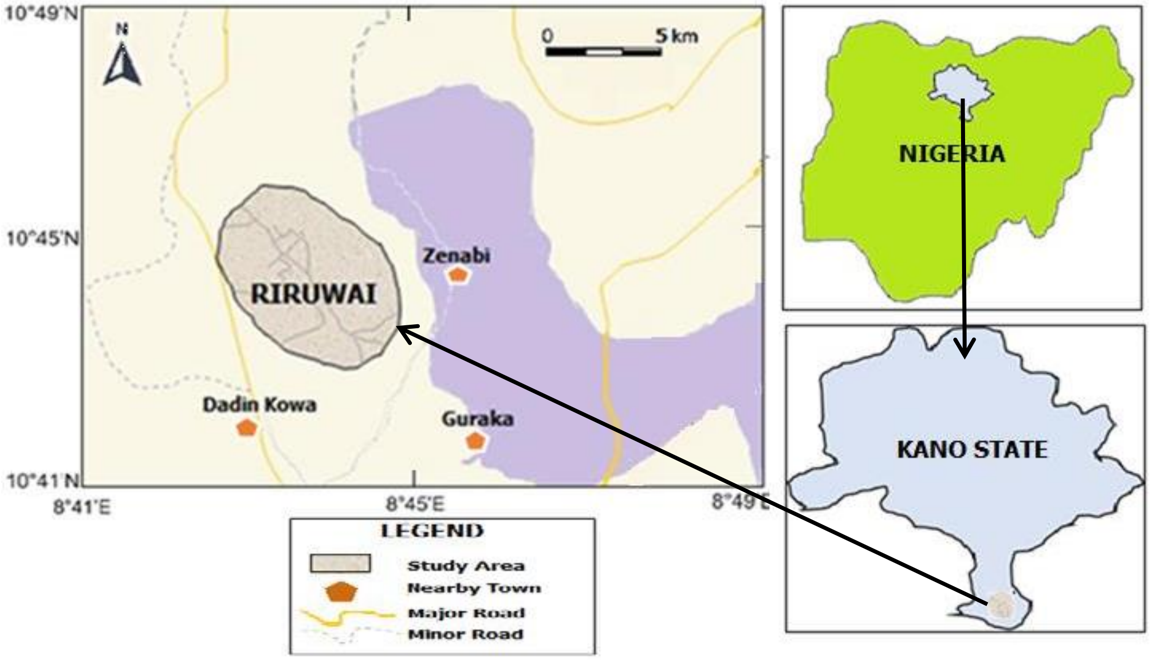

Fig 1: Map of the study area

2.3 Estimation of annual effective dose (AED)

The dose rate was used to estimate the Annual Effective Dose (AED) due to exposure to GRDL. The outdoor and indoor AED were calculated using equation 1 below

$$AED\ (mSv/yr) = GRDL(nGy/hr) \times 0.7(Sy/Gy) \times OF \times 8700\ hr \times 10^{-6} \quad (1)$$

where GRDL is the measured dose rate for each sampling point, 0.7 is the conversion factor to convert the absorbed dose rate to the effective dose equivalent in air received by an adult (ICRP 2018), OF is the occupancy factor equal to 0.2 for outdoor activities and 0.8 for indoor activities UNSCEAR 2010), 8700 hr is the number of hours in a year, and 10^{-6} is the conversion factor between nano and milli dimensions.

2.4 Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk (ELCR) is calculated using the computed annual effective dose equivalent (AED) is given by equation 2.

$$ELCR = AED \times ALE \times RF \quad (2)$$

where AED is the annual effective dose; ALE is the average life expectancy, which is 55.12 years for Nigeria according to the 2021 United nations projection, and RF is risk factor given as 0.05 Sv^{-1} (Akpanowo *et al.* 2020).

3.0 Results and Discussion

Table 1 shows the information on basic statistics for the measured GRDL. The results reveal that the radiation dose level range from 190 to 1300 nGy/hr, with a mean value of 749 ± 45.9 nGy/hr. The mean value is greater than the maximum permissible value (MPV) of 57 nGy/hr (UNSCEAR 2000). The data indicate that 95% confidence interval is between 687 nGy/hr and 900 nGy/hr, which is several folds higher than the recommended gamma dose limit. This range of values bounds the lower and upper statistic's mean of all the measurements. The observed background radiation is generally higher than the overall mean value of 143 nGy/hr, 221±35 nGy/hr and 89.70 nGy/hr reported by Abba *et al.* (2017), Akpanowo *et al.* (2020), Usikalu *et* *al*. (2019) for the mining areas of Barkin Ladi (in Plateau state), Anka (Zamfara State) and Ijero (Ekiti state) in Nigeria respectively. The values are also two, three, and one-half times higher than their corresponding world average and are lower by a factor of five, four and eight than the mean dose rate data obtained in the present study. However, in a study conducted by Aliyu *et al.* (2020) on Mazat and Kafi Habu mining sites of Plateau State (which have the same geology as the area of the present study), a geometrical mean value of 870 nGy/hr was recorded which is 14% higher than the recorded value for Riruwai. However, both results indicate that younger granites (igneous) formations present the highest dose rates as compared to sedimentary formations.

In Fig. 2, the frequency distribution curve for the GRDL is depicted. The figure indicates that about 50% of the recorded data were between 600 nGy/hr and 1000 nGy/hr with a few data points showing been close to 1300 nGy/hr.

Table 1: Summary of the basic statistics for GRDL

Statistics	Dose rate (DR) (nGy/hr)
Mean	749.0
SE	45.9
Range	190.0-1300.0
95% Conf. interval for mean	686.6-900.1
Maximum permissible value	57.0

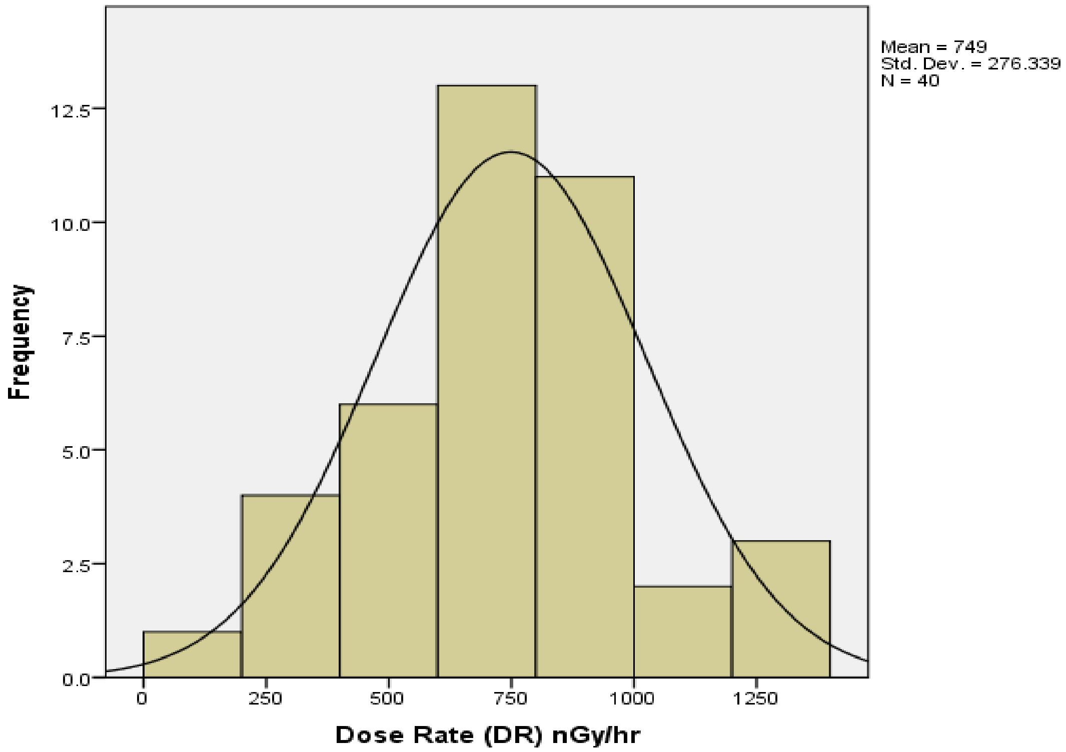

Fig. 2: Frequency distribution curve for dose rates

Tables 2 and 3 present descriptive statistics for the indoor and outdoor annual effective dose rates are presented. It can be seen from these results that the indoor AED values ranged from 0.23 mSv/yr to 1.58 mSv/yr with a mean value of 0.91 mSv/yr while that of the outdoor ranged from 0.93 mSv/yr to 6.33 mSv/yr with a mean value of and 3.65 mSv/yr. The computed mean indoor AED is within the maximum permissible value while the outdoor mean value is almost four times above the maximum permissible limit of 1 mSv/y (UNSCEAR 2010). The measured higher mean outdoor dose may be attributed to the mining activities within the zone. The results obtained for the annual outdoor dose rates indicate that the mining activity in the area has greatly enhanced the natural radioactivity. The mean indoor and outdoor annual effective doses recorded for the study area are comparable to those reported by (Adabanija *et al.* 2020) and (Aliyu *et al.* 2020) but significantly higher than the values reported (Abba *et al.* 2017, Usikalu *et al.* 2019, Akpanowo *et al.* 2020). The present authors opined that the similarity between the radiological data of AED reported may not be unconnected to their common geological formations since their study areas fall within the younger granite ring complexes.

Table 2: Indoor annual effective dose

Statistics	AED (mSv/yr)
Mean	0.910
SE	0.053
Range	0.230-1.580
95% Conf. interval for mean	0.760-1.040
Maximum permissible value	0.300-1.000

Table 3: Outdoor annual effective dose

Statistics	AED (mSv/yr)
Mean	3.650
SE	0.210
Range	0.930-6.330
95% Conf. interval for mean	3.230- 4.200
Maximum permissible value	1.000

The indoor and outdoor excess lifetime cancer risk (ELCR) computed for the area are presented in Tables 4 and 5 respectively. The mean ELCR value for indoor and outdoor AEDs due to the radiation dose was obtained as 2.51×10^{-3} and 10.50×10^{-3} respectively, with values at sampling points ranging from 0.64×10^{-3} to 4.36×10^{-3} for indoor and 2.55×10^{-3} to 17.46×10^{-3} for outdoor. It is clear from these tables that the computed ELCR for the area exceeds the recommended world average value of 0.29×10^{-3} and 1.16×10^{-3} for indoor and outdoor respectively (UNSCEAR 2000). In the study carried out by Akpanowo *et al*. (2020), ELCRs of 0.55×10^{-3} and 2.18×10^{-3} for indoor and outdoor were respectively recorded. The observed higher ELCR values obtained for all the sampling points in the present study indicate the need for caution against risk, especially by miners and other populace carrying out their activities around the mining sites as the values significantly exceed the world average value by a factor of 9 for both indoor and outdoor.

Table 4: Indoor expected life cancer risk

Statistics	ELCR $\times 10^{-3}$
Mean	2.51
SE	0.15
Range	0.64-4.36
95% Conf. interval for mean	2.10-2.90
World average value	0.29

Table 5: Outdoor expected life cancer risk

Statistics	ELCR $\times 10^{-3}$
Mean	10.5
SE	0.59
Range	2.55–17.46
95% Conf. interval for mean	8.81–11.23
World average value	1.16

A summary of all radiological data of interest for the forty (40) sampling points is presented in Table 6. The symbol "S" in the coding stands for the sampling locations. It is seen from this table that the minimum ELCR of 0.64×10^{-3} recorded at S_3 for the indoors exceeds the world average value by a factor of 2 while the maximum value of 4.36×10^{-3} recorded at S_9 exceeds the world average by a factor of 15. A similar increase is observed for outdoor ELCR for the same data points. The data presented in Table 6 indicate that higher radiation dose levels were obtained at sampling points S_9, S_{25}, S_{29}, S_{31} and S_3 suggesting a significant radiological index parameter of ELCR. The foregoing explanation shows that the miners and populace carrying out their activities close to these locations are at higher risk of getting exposed to a significant level of radiation and prone to radiation hazards.

Table 6: Summary of selected radiological data for all sampling points

S/N	Code	DR (μSv/hr)	DR (nGy/hr)	AED Indoor (mSv/yr)	AED Outdoor (mSv/yr)	ELCR Indoor $\times 10^{-3}$	ECLR outdoor $\times 10^{-3}$
1	S1	0.3	300	0.37	1.46	1.01	4.03
2	S2	0.2	200	0.24	0.97	0.67	2.69
3	S3	0.19	190	0.23	0.93	0.64	2.55
4	S4	0.22	220	0.27	1.07	0.74	2.95
5	S5	0.37	370	0.45	1.80	1.24	4.97
6	S6	0.61	610	0.74	2.97	2.05	8.19
7	S7	0.65	650	0.79	3.17	2.18	8.73
8	S8	0.57	570	0.69	2.78	1.91	7.65
9	S9	1.3	1300	1.58	6.33	4.36	17.46
10	S10	0.61	610	0.74	2.97	2.05	8.19
11	S11	0.88	880	1.07	4.29	2.95	11.82
12	S12	0.53	530	0.65	2.58	1.78	7.12
13	S13	0.78	780	0.95	3.80	2.62	10.47
14	S14	0.79	790	0.96	3.85	2.65	10.61
15	S15	0.77	770	0.94	3.75	2.58	10.34
16	S16	0.85	850	1.04	4.14	2.85	11.41
17	S17	0.79	790	0.96	3.85	2.65	10.61
18	S18	0.95	950	1.16	4.63	3.19	12.76
19	S19	0.8	800	0.97	3.89	2.66	10.74
20	S20	0.77	770	0.94	3.75	2.58	10.34
21	S21	0.75	750	0.91	3.65	2.52	10.07
22	S22	0.76	760	0.93	3.70	2.55	10.20
23	S23	0.92	920	1.12	4.48	3.09	12.35
24	S24	0.98	980	1.19	4.77	3.29	13.16
25	S25	1.09	1090	1.33	5.31	3.66	14.64
26	S26	0.95	950	1.16	4.63	3.19	12.76
27	S27	0.69	690	0.84	3.36	2.32	9.26
28	S28	0.73	730	0.89	3.56	2.45	9.80
29	S29	1.27	1270	1.55	6.19	4.26	17.05
30	S30	0.85	850	1.04	4.14	2.85	11.41
31	S31	1.15	1150	1.40	5.60	3.86	15.44
32	S32	0.43	430	0.52	2.09	1.44	5.77
33	S33	0.59	590	0.72	2.87	1.98	7.92
34	S34	0.58	580	0.71	2.83	1.95	7.79
35	S35	1.25	1250	1.52	6.09	4.19	16.78
36	S36	0.9	900	1.09	4.38	3.02	12.08
37	S37	0.51	510	0.62	2.48	1.71	6.85
38	S38	0.77	770	0.94	3.75	2.58	10.34
39	S39	0.96	960	1.17	4.68	3.22	12.89
40	S40	0.87	870	1.06	4.24	2.92	11.68

4.0 Conclusion

This study measured the gamma radiation dose levels of mining sites of Riruwai town of Kano State, Nigeria. A portable radiological survey meter is used in the measurement of dose rates from different locations of the mining sites. The results indicate that the mean dose rate of all the sampling points is 749 nGy/hr which is significantly higher than the recommended permissible limit of 57-59 nGy/hr set by the UNSCEAR. Assessment of radiological index parameters such as annual effective dose and excess lifetime cancer risk indicates a mean value of 0.91 mSv/yr and 2.51×10^{-3} for the indoor measurements and 3.65 mSv/yr and 10.5×10^{-3} for the outdoor measurement. These measured values are significantly higher than their corresponding world average values prescribed by both UNSCEAR and the International Commission on Radiological Protection (ICRP) signifying serious radiation exposure risk. The computed radiological hazard parameters are several-fold higher in human dose and cancer risks for most data points indicating that miners and dwellers around the study area are not safe. The findings of this study contribute to baseline radiological data that could be used for future studies. The present authors opined that the significant dose rate obtained in the study may not be unconnected to the geology and mining activities of tin and columbite that has been taken place in the area. It is recommended that further research on Naturally Occurring Radionuclide Materials (NORMs) particularly on Uranium and its progeny should be conducted on water and soil samples with a view to providing additional information on the reasons for higher gamma radiation dose rates around the mining areas and to quantify radiation exposure to miners and dwellers of the Riruwai town.

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