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Determination of Excess Lifetime Cancer Risk due to Gamma Radiation Exposure in Bompai Area, Kano State, Nigeria

[1]Mubarak B. Muhammad , [1]A. A Safana,
[1]Yakubu Mohammed, [1]Usman Muhammed Dauda

[1]Federal University Dutse,
Jigawa State,
Nigeria.

Email: asolarmubarakb@gmail.com

Abstract
This study assessed the levels of gamma radiation exposure and associated excess lifetime cancer risk (ELCR) in Bompai area, Kano State, Nigeria. Gamma dose rate measurements were taken at 500 points across residential, educational, healthcare, industrial, and commercial sites using Radiation Alert Inspector. The results showed a mean gamma dose level of 17.794×10^{-3} μSv/hr, corresponding to an annual effective dose (AED) of 380.2×10^{-6} mSv/yr and an ELCR of 1500×10^{-6}. Comparison with UNSCEAR guidelines revealed that the estimated AED and ELCR values are within safe limits, indicating no imminent health risks for residents. This study provides valuable radiological survey data for the area, highlighting the need for continued monitoring and future research with enhanced methodologies.

Keywords: Excess lifetime cancer risk (ELCR), Gamma radiation , Bompai Area.

INTRODUCTION
Background radiation measurement is crucial for understanding its impact on human health, particularly in urban areas with varying geological and environmental conditions. The assessment of gamma radiation exposure is essential for evaluating its contribution to the global non-internal dose.

Ionizing radiation, capable of causing ionization in matter, originates from natural and anthropogenic sources. Gamma radiation, a type of ionizing radiation, is emitted from radioactive decay or disintegration of atomic nuclei. Its effects on human health include direct chromosomal transformation, cancer induction, and circulatory system damage.

Gamma radiation exposure varies geographically due to differences in geological composition, soil mineral content, and elevation. This variability necessitates location-specific studies to accurately assess radiation exposure risks. In Nigeria, rapid urbanization and industrialization have increased the need for evaluating radiation exposure levels.

The environment primarily derives gamma radiation from natural sources, including cosmic radiation and terrestrial radionuclides. These sources are present in all ground formations at minimal concentrations due to natural radionuclides such as 238U, 232Th, and 40K in volcanic structures, phosphate-rich rocks, granite, and salt.

Author for Correspondence

Prolonged exposure to radiation can increase cancer risk. The annual effective dose (AED) quantifies radiation dosage, while excess lifetime cancer risk (ELCR) assesses potentially carcinogenic effects. Research has highlighted the vulnerability of pregnant women and children to radiation exposure.

Bompai area, Kano State, is undergoing rapid transformation, with residential and industrial zones emerging. The area's unique geology and industrial activities may elevate gamma radiation levels, potentially increasing health risks for inhabitants.

Recent studies have investigated background radiation levels globally. Shashikumar *et al.* (2022) assessed gamma-ray dose rates indoors and outdoors in Mandya district, India. Ateş *et al*. (2020) evaluated gamma dose rate and excess lifetime cancer risk in Bolu, Turkey. Maxwell et al. (2020) conducted a radiological study of Iju River, Nigeria.
Other studies have focused on urban areas. Joel *et al.* (2020) assessed gamma dose rate distribution in Ota, Nigeria. Shashikumar *et al. (2020)* studied indoor and outdoor gamma dose rates in Hassan City, Karnataka, India. *Zeb et al. (2020)* evaluated gamma exposure rates indoors and outdoors across urban centers in Pakistan.
Despite these studies, limited data exist on background radiation levels in Bompai area, Kano State. This study aims to quantify background radiation levels, compute radiological hazard indices, and establish baseline data for future research in the region.

METHODOLOGY

Study Area
The study area, Bompai, is located in Nasarawa LGA, Kano State, North-western Nigeria, within the coordinates 11.97194444ºN to 12.05027778ºN and 8.023888889ºE to 8.601944444ºE. It covers approximately 171,299 m² and is bordered by Minjibir, Gezawa, Dawakin Kudu, Madobi, and Tofa LGAs. The area's unique blend of residential and industrial activities, coupled with its geological characteristics, makes it an ideal location for investigating baseline gamma radiation levels and potential health implications for the local population (Onyenachi et al., 2023).

Sampling Technique
A systematic sampling approach was employed to collect data from 200 sample points across the study area. The points were divided into 4 sections, each comprising 50 points, spaced approximately 60 m apart. Measurements were taken at 1 m above ground level, using a GPS device to ensure accurate distance calculations. To account for temporal variations, readings were recorded three times daily (morning, afternoon, and evening), and an average value was calculated. The detector's response time was approximately 30 seconds per reading. This sampling design allowed for a comprehensive assessment of gamma radiation levels across the study area.

Instrumentation and Measurement
Gamma dose rates were measured using a Radiation Alert Inspector (RAI) dosimeter (S.E. International Inc., USA, Model 5250-0047, Serial Number 35636). The RAI features a Halogen-quenched, uncompensated GM tube with a thin mica window (areal density: 1.4-2.0 mg/cm², effective diameter: 45 mm). The detector measures gamma radiation up to 1000 μSv/h with a detection limit of 0.01 μSv/h.

Calibration

The RAI was calibrated using a standard Cesium-137 source, following the manufacturer's guidelines (SE International Inc.). The calibration process involved determining the background radiation count, then positioning the standard source at a distance corresponding to 5 mR/h, and updating the calibration factor. This process was repeated to validate accuracy, ensuring an average reading within ±10% of the expected value.

Measurement Procedure

Gamma dose rates were measured in-situ at 1 m above ground level. A portable GPS device (Garmin eTrex Legend, Garmin Ltd., 2007) recorded geocoordinates of measurement points. Measurements were taken directly using the RAI, with no additional calculations required.

Data Analysis

Excess Lifetime Cancer Risk (ELCR)

The excess lifetime cancer risk encompasses probable effects such as the likelihood of cancer occurrence in a given population over a specific life duration (Regassa *et al.*, 2023). This metric serves as a mechanism for evaluating and forecasting the probability of developing cancer due to exposure to low-dose radiation over an individual's lifetime. The equation for determining the excess lifetime cancer risk is given as follows (Raghu *et al.*, 2020):

$$ELCR = AED \times D_L \times R_F \quad (1.0)$$

where D_L is the average human lifespan (70 years), R_F stands for the risk factor (0.057 Sv^{-1}), and AED is the annual effective dose also referred to as whole-body dose (mSv/yr).

Software and Statistical Procedures

OriginPro 2021 and Surfer® Version 25.1.229 were employed to produce contour mapping/spatial dose rate distribution, Google Earth Pro Version 7.3.6.9796 was used to produce the map of the study area and detection points and descriptive statistical analysis was conducted using Microsoft Excel 2019. Charts used were produced using Microsoft Word 2019. ArcGis Version 10.3 was employed to produce radiological map of the study area.

RESULT AND DISCUSSION

Gamma Dose Rate

Gamma dose rates were measured at 200 detection points in Bompai Area, Kano State, Nigeria, using a Radiation Alert Inspector device. The results are presented in Tables 1.1 (a-b) and 2.1 (a-b). The measured gamma dose rates ranged from 8.5×10^{-3} µSv/h (Sub-area 3 and 4) to 73.5×10^{-3} µSv/h (Sub-area 4), with a mean dose rate of 19.9×10^{-3} µSv/h for the study area. A contour map was used to visualize the dose rate distribution, with grey and black colors representing high and low concentrations, respectively.

Table 1.1 a: Average gamma dose rate for Sub-areas 1 and 2

S/No.	γ-DR ($x10^{-3}$ μSv/hr)	Geocoordinates		S/No.	γ-DR ($x10^{-3}$ μSv/hr)	Geocoordinates	
		Lat. (ºN)	Long. (ºE)			Lat. (ºN)	Long. (ºE)
Sub-area 1				Sub-area 2			
1	19.0	12.015	8.575278	1	17.5	11.97194	8.598889
2	18.5	12.015	8.574444	2	19.5	12.01361	8.569722
3	10.0	12.01611	8.574167	3	15.5	12.01417	8.569722
4	14.0	12.01778	8.573889	4	20.0	12.01361	8.566389
5	17.0	12.0175	8.572222	5	15.5	12.01417	8.566389
6	14.5	12.01611	8.5725	6	11.5	12.01306	8.566111
7	14.0	12.01444	8.573056	7	14.0	12.01222	8.565556
8	17.5	12.01444	8.571944	8	17.0	12.01139	8.565556
9	16.5	12.01444	8.570833	9	16.0	12.01	8.565000
10	15.5	12.01361	8.569722	10	17.0	12.00889	8.565000
11	29.5	12.00944	8.569444	11	13.0	12.00778	8.564722
12	17.5	12.01139	8.570556	12	15.0	12.00667	8.565000
13	19.0	12.01111	8.571389	13	19.0	12.00778	8.563056
14	11.5	12.01111	8.572222	14	20.0	12.01083	8.566389
15	11.5	12.01056	8.573056	15	23.5	12.01222	8.566111
16	16.0	12.01028	8.571667	16	16.5	12.01361	8.565278
17	19.5	12.01028	8.570556	17	23.0	12.01417	8.565000
18	15.0	12.01056	8.569722	18	15.0	12.01417	8.563611
19	29.5	12.00972	8.569444	19	18.0	12.01139	8.563333
20	26.5	12.00833	8.569444	20	15.0	12.01083	8.561667
21	16.5	12.00778	8.569444	21	14.5	12.00944	8.561389
22	13.0	12.01278	8.568889	22	14.5	12.00806	8.561111
23	22.0	12.01278	8.568889	23	16.5	12.00694	8.561111
24	17.0	12.01000	8.568889	24	13.5	12.00694	8.559444
25	15.0	12.00889	8.568611	25	16.0	12.00889	8.559444
26	18.5	12.00750	8.568611	26	15.5	12.01083	8.560000
27	16.0	12.01194	8.568056	27	14.5	12.01333	8.568056
28	16.5	12.01083	8.567222	28	15.0	12.01556	8.568333
29	18.0	12.00917	8.567222	29	11.5	12.01639	8.568056
30	21.5	12.00750	8.567222	30	11.5	12.01694	8.567222
31	13.0	12.01472	8.573889	31	18.5	12.01667	8.565556
32	18.0	12.0175	8.574722	32	13.0	12.01583	8.563889
33	17.5	12.01694	8.574722	33	18.0	12.01556	8.562500
34	19.5	12.01694	8.576111	34	18.5	12.01389	8.560278
35	12.5	12.01417	8.575833	35	8.5	12.01250	8.560278
36	10.5	12.01278	8.576111	36	20.5	12.00889	8.562222
37	21.0	12.01139	8.575556	37	13.0	12.01000	8.563611
38	22.5	12.01083	8.574722	38	13.5	12.01139	8.563889
39	18.5	12.00972	8.573889	39	9.5	12.00833	8.563333
40	20.0	12.01083	8.576944	40	13.5	12.00694	8.563333
41	15.5	12.00972	8.577222	41	13.5	12.00639	8.563333
42	13.0	12.00917	8.576111	42	12.0	12.00639	8.564167
43	15.0	12.00861	8.575278	43	19.5	12.00694	8.561944
44	17.0	12.00833	8.573889	44	13.0	12.00778	8.564444
45	17.5	12.00833	8.573889	45	16.5	12.00694	8.565556
46	14.5	12.00889	8.571944	46	17.0	12.00694	8.565833
47	17.5	12.00889	8.570556	47	19.0	12.00694	8.567778
48	20.5	12.01111	8.568889	48	16.0	12.00028	8.571667
49	21.5	12.01417	8.568889	49	14.5	12.00333	8.573333
50	11.5	12.01028	8.569167	50	19.0	12.00806	8.578889
Max.	29.5				23.5		
Min.	10.0				8.5		
Mean	17.3				15.8		

Table 1.1a presents the result of gamma dose rate measurement for sub-areas 1 and 2 (Fig. 1) along with location data for each detection point. From the table, the mean, maximum and minimum dose rates for the two sub-areas are 17.3x10^{-3} μSv/hr & 15.8x10^{-3} μSv/hr, 29.5x10^{-3} μSv/hr & 23.5x10^{-3} μSv/hr, and 10.0 x10^{-3} μSv/hr and 8.5 x10^{-3} μSv/hr, respectively.

Fig. 1: Sub-areas 1 and 2

To put these into context, places under sub-area 1 include Gaskiya Textiles Company, Little Genius Schools, Standard (shoes) Company Ltd., KASCO (Fertilizer blending plant/Livestock feed mill plant), Sunflower Schools, Dantata Plastic Company Ltd., SALVIN Plastic Company, residential areas, SOLAR Fertilizer & Chemicals Company Ltd., Green Palace Hotels, PALI Resort Hotel, and AL-HAMSAD Rice Company. Similarly, sub-area 2 consists mostly of residential areas, Doctor's Clinic, Porto Golf Hotels, furniture manufacturing company, rice mill company, and manual stone crushing site. By comparison, the average values of sub-areas 1 and 2 are lower than the global average value of 59x10^{-3} μSv/h (Suresh *et al.*, 2021). This indicates that there is no relationship between background gamma dose rate and presence of plastic manufacturing and fertilizer blending companies. Furthermore, Fig. 2 represents the distribution of gamma dose rate in sub-areas 1 and 2.

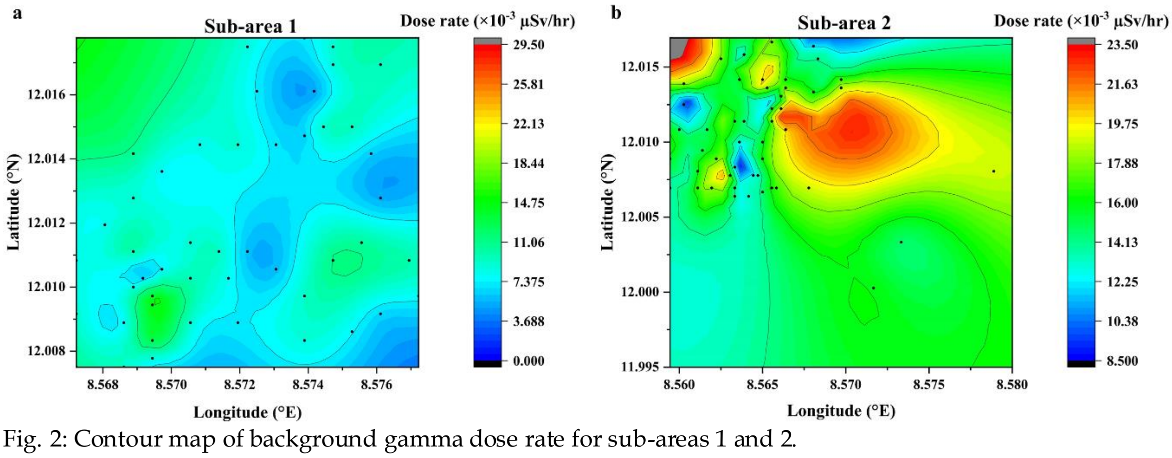

Fig. 2: Contour map of background gamma dose rate for sub-areas 1 and 2.

Table 1.1 b: Average gamma dose rate for Sub-areas 3 and 4

S/No.	γ-DR (x10-3 μSv/hr)	Geocoordinates		S/No.	γ-DR (x10-3 μSv/hr)	Geocoordinates	
		Lat. (ºN)	Long. (ºE)			Lat. (ºN)	Long. (ºE)
Sub-area 3				Sub-area 4			
1	17.0	12.02139	8.572500	1	16.0	12.02194	8.577222
2	16.0	12.02028	8.572500	2	14.5	12.02167	8.578333
3	15.0	12.01889	8.572222	3	15.0	12.02167	8.579722
4	8.5	12.01778	8.571111	4	23.5	12.02194	8.581389
5	19.5	12.01750	8.572222	5	22.0	12.02222	8.583056
6	22.0	12.01861	8.570556	6	23.5	12.02250	8.584167
7	14.0	12.02000	8.570833	7	18.0	12.02306	8.585556
8	18.0	12.01778	8.569722	8	20.5	12.02361	8.587778
9	15.0	12.01750	8.568333	9	14.0	12.02361	8.591111
10	19.0	12.01667	8.568056	10	15.0	12.02389	8.591667
11	10.5	12.01750	8.573889	11	23.0	12.02389	8.592778
12	20.0	12.04889	8.571389	12	26.5	12.02417	8.593889
13	17.5	12.03278	8.573611	13	23.5	12.02417	8.595278
14	14.5	12.01750	8.576389	14	16.0	12.02444	8.596667
15	12.5	12.01861	8.575556	15	23.0	12.02472	8.597778
16	20.0	12.01750	8.576667	16	15.0	12.02500	8.598889
17	16.0	12.01750	8.576389	17	14.5	12.02500	8.600000
18	15.0	12.02083	8.578889	18	19.5	12.02528	8.601667
19	17.0	12.01806	8.570278	19	19.0	12.02389	8.601944
20	13.5	12.01833	8.572500	20	14.5	12.02556	8.595833
21	17.0	12.01833	8.571667	21	22.0	12.02556	8.595833
22	12.0	12.02167	8.571389	22	20.0	12.02472	8.593056
23	9.5	12.02111	8.568611	23	23.0	12.02583	8.593056
24	14.0	12.02194	8.567778	24	19.0	12.02472	8.592222
25	17.0	12.0175	8.574167	25	14.5	12.02611	8.591944
26	17.5	12.01722	8.571389	26	17.0	12.02361	8.592222
27	15.0	12.01722	8.573056	27	13.5	12.02194	8.592222
28	14.5	12.01667	8.568611	28	17.0	12.02472	8.590556
29	9.0	12.01917	8.571111	29	13.0	12.02639	8.590278
30	15.5	12.02139	8.575833	30	25.5	12.02194	8.588056
31	15.5	12.02139	8.568611	31	17.0	12.02194	8.590000
32	22.0	12.02083	8.568611	32	23.0	12.02194	8.588056
33	17.5	12.02278	8.569167	33	19.5	12.02278	8.583889
34	16.5	12.02361	8.569167	34	16.5	12.02083	8.581389
35	11.0	12.02472	8.578056	35	11.0	12.01972	8.581667
36	16.5	12.02056	8.568333	36	29.5	12.02139	8.591389
37	11.5	12.01972	8.573333	37	36.5	12.01944	8.592500
38	15.0	12.01972	8.574722	38	47.0	12.02889	8.591111
39	17.0	12.02000	8.575278	39	57.0	12.02139	8.593333
40	11.0	12.02000	8.571667	40	58.5	12.01972	8.590000
41	13.0	12.01667	8.568611	41	57.5	12.02361	8.598056
42	10.5	12.01972	8.572222	42	64.0	12.01861	8.588611
43	12.5	12.01722	8.570556	43	67.0	12.02639	8.594444
44	15.5	12.01694	8.571944	44	70.5	12.02722	8.595556
45	20.0	12.01778	8.570278	45	64.0	12.01861	8.587222
46	18.5	12.01833	8.575278	46	72.5	12.0225	8.588611
47	18.5	12.02028	8.571944	47	71.5	12.01833	8.599167
48	17.5	12.02333	8.569722	48	68.5	12.01667	8.586944
49	14.5	12.01889	8.570556	49	64.5	12.01667	8.588889
50	17.0	12.02139	8.568056	50	73.5	12.02194	8.596389
Max.	22.0			Max.	73.5		
Min.	8.5			Min.	11.0		
Mean	15.5			Mean	31.0		

Table 1.1b presents the obtained measurement of the background gamma dose rate levels in sub-areas 3 and 4 of the study area (Fig. 2). The maximum recorded dose rate in the sub-area 3 and 4 is 22.0x10^{-3} µSv/hr and 73.5x10^{-3} µSv/hr respectively, while the minimum dose rate is 8.5x10^{-3} µSv/hr and 11.0x10^{-3} µSv/hr. The mean dose rate level for the two sub-areas is 15.5x10^{-3} µSv/hr and 31.0x10^{-3} µSv/hr, respectively.

Fig. 3: Detection points in sub-areas 3 and 4

Places in these sub-areas include public buildings, fertilizer company (KASCO), STANDARD shoes company, tannery. Al-Hamsad rice company, Woolen thread company, rubber mat producing company, First Bank PLC Bompai Branch, Nigeria customs barracks, magistrate court, stone crushing site, public and private schools, plastic industries, groundnut oil producing companies, residential areas, ASAD pharmaceutical company, AL-BESAL Foods (Masavita) Nig. Ltd. The distribution of gamma dose rate in these areas is depicted in Fig. 4.

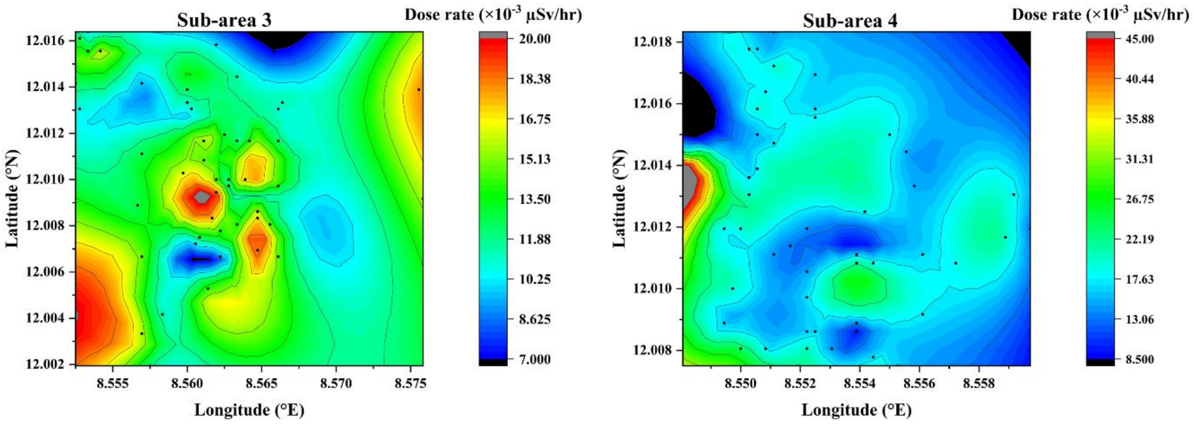

Fig. 4: Contour map for sub-areas 3 and 4

Annual Effective Dose and Excess Lifetime Cancer Risk

The annual effective dose and excess lifetime cancer risk as a result of exposure to the background gamma dose in the study area is evaluated using equations 3.1 and 3.2 and the result obtained are presented in Tables 2.1 (a-b). The highest value recorded in the study area is 901.4x10^{-6} mSv/yr and 360010^{-6} for AED and ELCR respectively while the lowest value is 85.8x10^{-6} mSv/yr and 342.5x10^{-6} respectively. Additionally, the average AED and ELCR evaluated for the entire study area are 218.2x10^{-6} mSv/yr and 870.7x10^{-6}, far lower than the recommended limit of AED (70 µSv/yr) and ELCR (0.29x10^{-3}) respectively, set by UNSCEAR (UNSCEAR, 2000).

Table 2 a: AED and ELCR for Sub-areas 1 and 2

S/No.	AED ($x10^{-6}$ mSv/yr)	ELCR ($x10^{-6}$)	S/No.	AED ($x10^{-6}$ mSv/yr)	ELCR ($x10^{-6}$)
Sub-area 1			Sub-area 2		
1	233.0	929.7	1	214.6	856.3
2	226.9	905.3	2	239.1	954.2
3	122.6	489.3	3	190.1	758.5
4	171.7	685.1	4	245.3	978.7
5	208.5	831.9	5	190.1	758.5
6	177.8	709.5	6	141.0	562.7
7	171.7	685.1	7	171.7	685.1
8	214.6	856.3	8	208.5	831.9
9	202.4	807.4	9	196.2	782.9
10	190.1	758.5	10	208.5	831.9
11	361.8	1400	11	159.4	636.1
12	214.6	856.3	12	184.0	734.0
13	233.0	929.7	13	233.0	929.7
14	141.0	562.7	14	245.3	978.7
15	141.0	562.7	15	288.2	1100
16	196.2	782.9	16	202.4	807.4
17	239.1	954.2	17	282.1	1100
18	184.0	734.0	18	184.0	734.0
19	361.8	1400	19	220.8	880.8
20	325.0	1300	20	184.0	734.0
21	202.4	807.4	21	177.8	709.5
22	159.4	636.1	22	177.8	709.5
23	269.8	1100	23	202.4	807.4
24	208.5	831.9	24	165.6	660.6
25	184.0	734.0	25	196.2	782.9
26	226.9	905.3	26	190.1	758.5
27	196.2	782.9	27	177.8	709.5
28	202.4	807.4	28	184.0	734.0
29	220.8	880.8	29	141.0	562.7
30	263.7	1100	30	141.0	562.7
31	159.4	636.1	31	226.9	905.3
32	220.8	880.8	32	159.4	636.1
33	214.6	856.3	33	220.8	880.8
34	239.1	954.2	34	226.9	905.3
35	153.3	611.7	35	104.2	415.9
36	128.8	513.8	36	251.4	1000
37	257.5	1000	37	159.4	636.1
38	275.9	1100	38	165.6	660.6
39	226.9	905.3	39	116.5	464.9
40	245.3	978.7	40	165.6	660.6
41	190.1	758.5	41	165.6	660.6
42	159.4	636.1	42	147.2	587.2
43	184.0	734.0	43	239.1	954.2
44	208.5	831.9	44	159.4	636.1
45	214.6	856.3	45	202.4	807.4
46	177.8	709.5	46	208.5	831.9
47	214.6	856.3	47	233.0	929.7
48	251.4	1000	48	196.2	782.9
49	263.7	1100	49	177.8	709.5
50	141.0	562.7	50	233.0	929.7
Max.	361.8	1400	Max.	288.2	1100
Min.	122.6	489.3	Min.	104.2	415.9
Mean	211.6	844.1	Mean	194.0	774.1

Table 2.1a displays the AED and ELCR due to gamma dose in sub-areas 1 and 2 of the study area. The AED ranges from a maximum of 361.8 x 10^{-6} to a minimum of 122.6 x 10^{-6} mSv/yr for sub-area 1, with an average of 211.6 x 10^{-6} mSv/yr. In sub-area 2, a maximum AED value of 288.2 x 10^{-6} mSv/yr, a minimum of 104.2 x 10^{-6} mSv/yr and an average of 194.0 x 10^{-6} mSv/yr were evaluated. These values are considerably lower than the recommended dose limit. Similarly, the ELCR values ranges from a maximum of 1400 x 10^{-6} to a minimum of 489.3 x 10^{-6} with an average value of 844.1 x 10^{-6} for sub-area 1. For sub-area 2, the maximum ELCR evaluated is 1100 x 10^{-6} and a minimum value of 415.9 x 10^{-6} while the average value of the sub-area is 774.1 x 10^{-6} less than the recommended dose limit.

Table 2.1 b: AED and ELCR for Sub-areas 3 and 4

S/No.	AED (x10^{-6} mSv/yr)	ELCR (x10^{-6})	S/No.	AED (x10^{-6} mSv/yr)	ELCR (x10^{-6})
Sub-area 3			Sub-area 4		
1	208.5	831.9	1	196.2	782.9
2	196.2	782.9	2	177.8	709.5
3	184.0	734.0	3	184.0	734.0
4	104.2	415.9	4	288.2	1100
5	239.1	954.2	5	269.8	1100
6	269.8	1100	6	288.2	1100
7	171.7	685.1	7	220.8	880.8
8	220.8	880.8	8	251.4	1000
9	184.0	734.0	9	171.7	685.1
10	233.0	929.7	10	184.0	734.0
11	128.8	513.8	11	282.1	1100
12	245.3	978.7	12	325.0	1300
13	214.6	856.3	13	288.2	1100
14	177.8	709.5	14	196.2	782.9
15	153.3	611.7	15	282.1	1100
16	245.3	978.7	16	184.0	734.0
17	196.2	782.9	17	177.8	709.5
18	184.0	734.0	18	239.1	954.2
19	208.5	831.9	19	233.0	929.7
20	165.6	660.6	20	177.8	709.5
21	208.5	831.9	21	269.8	1100
22	147.2	587.2	22	245.3	978.7
23	116.5	464.9	23	282.1	1100
24	171.7	685.1	24	233.0	929.7
25	208.5	831.9	25	177.8	709.5
26	214.6	856.3	26	208.5	831.9
27	184.0	734.0	27	165.6	660.6
28	177.8	709.5	28	208.5	831.9
29	110.4	440.4	29	159.4	636.1
30	190.1	758.5	30	312.7	1200
31	190.1	758.5	31	208.5	831.9
32	269.8	1100	32	282.1	1100
33	214.6	856.3	33	239.1	954.2
34	202.4	807.4	34	202.4	807.4
35	134.9	538.3	35	134.9	538.3
36	202.4	807.4	36	361.8	1400
37	141.0	562.7	37	447.6	1800
38	184.0	734.0	38	576.4	2300
39	208.5	831.9	39	699.0	2800
40	134.9	538.3	40	717.4	2900
41	159.4	636.1	41	705.2	2800
42	128.8	513.8	42	784.9	3100

43	153.3	611.7	43	821.7	3300
44	190.1	758.5	44	864.6	3400
45	245.3	978.7	45	784.9	3100
46	226.9	905.3	46	889.1	3500
47	226.9	905.3	47	876.9	3500
48	214.6	856.3	48	840.1	3400
49	177.8	709.5	49	791.0	3200
50	208.5	831.9	50	901.4	3600
Max.	269.8	1100	Max.	901.4	3600
Min.	104.2	415.9	Min.	134.9	538.3
Mean	189.5	756.0	Mean	380.2	1500

Table 2.1b presents the AED and ELCR resulting from gamma radiation exposure in sub-areas 3 and 4 within the study region. The AED in sub-area 3 varies from 269.8x10^{-6} to 104.2x10^{-6} mSv/yr, averaging at 189.5x10^{-6} mSv/yr. In sub-area 4, the AED ranges from 901.4x10^{-6} to 134.9x10^{-6} mSv/yr, with an average of 380.2x10^{-6} mSv/yr. These levels are notably below the recommended dose threshold. Similarly, the ELCR in sub-area 3 spans from 1100x10^{-6} to 415.9x10^{-6}, with an average of 756.0x10^{-6}. For sub-area 4, the ELCR varies from 3600x10^{-6} to 538.3x10^{-6}, with an average of 1500x10^{-6} falling under the recommended limit.

Discussion

It was observed that the average gamma dose rate, AED and ELCR were all lower than the average reported in other study studies as summarised in Table 3.

Table 3: Comparison of gamma dose rate, AED and ELCR in this study with literature

Study area	Average dose rate	AED	ELCR	Ref.
Northern Bauchi	165.48 μSvh^{-1}	1.014 $mSvy^{-1}$	-	(Ibrahim *et al.*, 2023)
Katsina State	116 ± 1 μSvh^{-1}	0.711 $mSvy^{-1}$	5.79x10^{-4}	(Garba *et al.*, 2023)
India	91 μSvh^{-1}	0.11 $mSvy^{-1}$	-	(Mitra *et al.*, 2023)
Idiroko Road, Ota, Ogun State	73.57 μSvh^{-1}	-	-	(Omeje *et al.*, 2023)
Nkalagu quarry, Nigeria	1.5×10^{-4} μSvh^{-1}			
Siddipet, Telanagana State	235±47 μSvh^{-1}	-	1.01x10^{-3} ± 0.17x10^{-3}	(Vinay Kumar Reddy *et al.*, 2023)
Dutse, Jigawa State	0.015 μSvh^{-1}	17.29 $\mu Svyr^{-1}$	0.061x10^{-3}	(U-Dankawu *et al.*, 2023)
Bompai Area	17.794x10^{-3} μSv/hr	218.2x10^{-6} mSv/yr	870.7x10^{-6}	This work

CONCLUSION

In this study, we have attempted to measure the level of background gamma dose rate in Bompai area of Kano State. Using the measurement, we have estimated the annual effective dose and the excess lifetime cancer risk for the study area. These radiological indices of AED and ELCR were found to be lower than the recommended limit of AED 70 μSv/yr and 0.29x10^{-3} respectively, set by UNSCEAR (UNSCEAR, 2000).

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