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Assessment of Natural Radioactivity Levels and Radiation Hazard Indices in Selected Areas of Jos Metropolis.

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ABSTRACT

Assessment of the background radiation dose from different locations in Jos metropolis and environs within Naraguta Sheet 168NE was carried out using a BGO (Bismuth Germanate Oxide) Gamma Spectrometer RS-230 to determine the concentrations of values of Potassium (^{40}K), Uranium (^{238}U) and Thorium (^{232}Th) with which radiation hazard parameters were calculated. The results obtained showed concentration values of 0.2%-11%, 0.2 ppm-34.7 ppm and 0.3 ppm-136.3 ppm for Potassium (^{40}K), Uranium (^{238}U) and Thorium (^{232}Th), respectively. Activity concentration of these radionuclides varied from 51.28-2717.95 Bq/Kg for Potassium (^{40}K), 2.47-428.40 Bq/Kg for Uranium (^{238}U) and 1.22-554.07 Bq/Kg for Thorium (^{232}Th), with the areas around Bitsichi having the highest values of uranium (^{238}U) and thorium (^{232}Th). Radiological parameters such as radium equivalent, internal hazard indices, absorbed dose rate indoor, annual effective dose equivalent, excess lifetime cancer risk and annual gonadal equivalent dose were all calculated, and the values obtained were 85.16-1420.12 Bq/Kg, 0.24-4.99, 38.80-832.00nGyh^{-1}, 0.18-3.83mSvy^{-1}, 0.63 x10^{-3}-13.39x10^{-3} and 342.83-4452.91µSvy^{-1}, respectively. These values in some locations are higher than the recommended limit of 1mSvy^{-1}. The possible impact of these ionizing radiations on humans and also the genetic engineering process was assessed, suggesting possible radiation-related risks for the lifeforms or inhabitants of buildings within the studied location over time.

Keywords: Ionizing Radiation, Radionuclides, Potassium (40K), Uranium (238U), Thorium (232Th), Radium Equivalent (Raeq), Internal Hazard (Hin), External Hazard (Hex), Absorbed Dose Rate (D), Annual Effective Dose Equivalent (AEDE), Excess Lifetime.

INTRODUCTION

Ionizing radiation consists of high-energy electromagnetic waves (like X-rays and gamma rays) or particles (alpha particles, beta particles, or neutrons) with enough energy to detach electrons from atoms, a process called ionization. This can damage cells, DNA, and tissues, potentially leading to health effects like cancer or radiation sickness (WHO, 2023). Ionizing radiation impacts genetic engineering by causing DNA damage, such as double-strand breaks (DSBs), which can lead to mutations (Lanfang *et al,* 2025). If this DNA damage is carefully studied, the mutations observed can sometimes be used in mutation breeding to induce genetic variability for selecting plants or microorganisms with desirable traits. However, this radiation-induced damage can also cause chromosomal instability, cell death, or potentially contribute to conditions like cancer if the damage isn't repaired correctly (Lanfang *et al,* 2025). Indoor exposures to gamma radiation depend on the time spent indoors per day, as well as the construction materials used (Solomon *et al,* 2018). The greatest contribution to the average public radiation exposure comes from radioactive elements in the earth's crust and from cosmic radiation originating in space (Solomon *et al* 2018). Natural sources contribute, on average, about 98% of the human radiation dose, excluding medical exposures (Ajayi, 2008). The global average dose from natural sources is estimated to be about 2.4mSv/y (Ajayi, 2008). In building construction, e.g laboratories or offices for public or private purposes, most of the sand materials used for building construction are derived from rock and soil, which contain different amounts of ^{238}U, ^{232}Th and ^{40}K, thereby making them radioactive as well as causing ionizing radiation (Solomon *et al.,* 2018).

Jibiri *et al.* (2009) worked on farming activities on the sand situated in high background radiation (HBR) areas in Jos and recorded that farming activities enhance the radiation exposure scenarios

and pathways to humans. According to this report, annual external dose values vary from 0.07mSv/y - 2.02mSv/y while the internal dose values for the locations were reported as 9.9mSv/y for Bitsichi, 3.9mSv/y for Bukuru and 3.9mSv/y for Ropp. Ajayi (2008) reported that the radiation background values of Tin Mining sites in Jos have an equivalent dose of 3.0mSv/y due to the gamma radiation from the radionuclides ^{40}K, ^{238}U and ^{232}Th in the soil samples surrounding the mining sites. Though the value is below the average dose value for Radiation workers (20mSv/y), it's far above the world/global safety value of 1mSv/y as reported by the UNSCEAR (2000). Radionuclide concentration and lifetime cancer risk due to gamma radioactivity from Quarry Stone Aggregates in Jos and its Environs, North Central Nigeria, were studied by Solomon *et al.* (2018). The report shows the concentration and specific activity of ^{238}U, ^{232}Th and ^{40}K with their respective radiological indices from the various quarries. According to the report, the average total Excess Lifetime Cancer Risk from the quarries was $4.45x10^{-3}$, which is 15.34 times higher than the world average of $0.29x10^{-3}$, below which there is a negligible risk of developing cancer. Jos metropolis and its environs fall within areas where active tin mining activities are taking place. As a result of these mining activities, radioactive minerals associated with the mined deposits were exposed to the surface, thereby elevating the background radiation of the entire environment. The experience of lead-poisoning cases in Zamfara from 2011-2012 necessitated this research to assess the background radiation level and its possible ionizing radiation impacts in Jos metropolis and environs.

MATERIALS AND METHODS

Materials

Materials used for the data collection purpose includes: a topographic map of Naraguta sheet 168NE, a field notebook, pen, ruler, GARMIN GPSmap 62 model for taking coordinates, Compass Clinometer for taking strikes, dip and direction of movement within the study area and a hand-held Gamma Ray Spectrometer, BGO-SUPER-SPEC (RS-230) model used in taking radioactivity values across the areas of study.



Plate 1: Gamma Ray Spectrometer,



Plate 2: Taking background radiation from sand-mining site.

Methods

A hand-held Gamma Ray Spectrometer BGO-SUPER-SPEC (RS-230) model was carefully place on the surface of the desired areas to be assessed to take the measurement of gamma radiation emanating from the naturally radioactive constituents across different locations within the study area to take note of the concentrations of ^{238}U, ^{232}Th and ^{40}K at each of the selected location; Gero, Dogo-Na_Hauwa, Lejengre, Du, Bitsichi, Rayfield Resort, Bukuru, Gold and Base, Stream Channel Amusement Part, Mazah, Busa-Buji, Odus. The spectrometer is a handheld auto-stabilized 1024 channel piece of equipment which uses a large (103 cm^3) BGO (Bismuth Germanate Oxide) detector for an improved level of system sensitivity and accuracy, with an improved/significant increase in performance over the normal NaI detector. For better accuracy, a preset time of 120 seconds was used for the measurement per point, while the assay mode provided the concentrations of Potassium (K %), equivalent Thorium (eTh) in ppm, and equivalent Uranium (eU) in ppm for each point of measurement. The energy response of the equipment is 30-3000kev. From the measurements

recorded, the values were then converted into activity concentrations in Bqkg^{-1} with which hazards were determined.
The various hazards indices recorded where calculated and presented using the formulas below;

Radium Equivalent Activity (Ra*eq*): This is an index that sums up the gamma output of ^{238}U, ^{232}Th and ^{40}K emanating from the sand mining points across different locations studied. Radium equivalent activity was calculated using the UNSCEAR (2000) formula as follows;

$$Ra_{eq}\ (Bq/kg) = A_{Ra} + 1.45A_{Th} + 0.077A_K$$

Where A_{Ra}, A_{Th} and A_K are the specific activity concentrations of uranium (^{238}U), Thorium (^{232}Th) and Potassium (^{40}K), respectively.

Internal and External Hazards: The internal hazard and external hazard are reflections of radiation exposure. These hazard indices were calculated using equations 4 and 5 of Shoeib and Thabayneh (2014)

$$H_{In} = A_U/185 + A_{Th}/259 + A_K/4810 \quad (4)$$
$$H_{Ex} = A_U/370 + A_{Th}/259 + A_K/4810 \quad (5)$$

Where A_U, A_{Th} and A_K are the specific activity concentrations of uranium (^{238}U), Thorium (^{232}Th) and Potassium (^{40}K), respectively. The acceptable limit of safety for the mean internal and external hazard indices should be less than 1.

Absorbed Dose Rate: The absorbed dose rate in the air was calculated using the Beretka & Mathew (1985) and UNSCEAR (2000) equation 1

$$D_{in\ air}\ (nGy/h) = 0.462xCu + 0.604xCth + 0.041xCk \quad (1)$$

Where 0.462, 0.604 and 0.041 are the conversion factors for ^{238}U, ^{232}Th and ^{40}K, respectively. The average dose rate recorded ranges between 38.8nGy/h – 832nGy/h as shown in Table 2

Annual Effective Dose Equivalent (*AEDE*): To determine the annual effective dose equivalent (indoor and outdoor), the following equation was used: Beretka & Mathew (1985), and UNSCEAR (2000) equations 2 and 3

$$AEDE_{indoor}\ (mSvy^{-1}) = D(nGy^{-1}) \times 8760hy^{-1} \times 0.75 \times 0.7SvGy^{-1} \times 10^{-6} \quad (2)$$
$$AEDE_{outdoor}\ (mSvy^{-1}) = D(nGy^{-1}) \times 8760hy^{-1} \times 0.25 \times 0.7SvGy^{-1} \times 10^{-6} \quad (3)$$

Where 8760 is the total number of hours in a year (24hrs *x* 365days), 0.75 is the indoor occupancy factor, which was estimated at 18hrs a day, 0.25 is the outdoor occupancy factor, which was estimated at 6hrs a day, while $0.7SvGy^{-1}$ is the conversion coefficient from the absorbed effective dose received. Average $AEDE_{indoor}$ recorded across the area of study falls within the range of 0.465-1.012 $mSvy^{-1}$ while the average $AEDE_{outdoor}$ recorded was between 0.11-0.28 $mSvy^{-1}$ as seen in Table 2. The permissible limit according to WHO is 1mSv/y.

Excess Lifetime Cancer Risk (*ELCR*): This is the estimate of an additional risk for someone developing cancer as a result of exposure to toxic substances or radionuclides over a long period of time. Emelue *et al.* (2014) outlined the formula for ELCR (indoor and outdoor) as follows;

$$ELCR_{indoor} = AEDEin \times DL(70) \times RF(0.05)$$
$$ELCR_{outdoor} = AEDE_{out} \times DL(70) \times RF(0.05)$$

Where DL is the average duration of life, which was pegged at 70, while RF is the risk factor per sievert, which was pegged at 0.05*Sv* for public exposure by the International Committee on Radiation Protection (ICRP), 1991. The average values obtained across the study area range between 1.628×10^{-3} – 3.542×10^{-3} (indoor) and 0.543×10^{-3} – 1.181×10^{-3} (outdoor), which was by far above the reference value of $0.29x10^{-3}$ set (Aziz *et al.* 2014, Solomon *et al.* 2018) with the Bitsichi sand having

the worst ELCR values. This can be seen in Table 2.

Annual Gonadal Equivalent Dose (*AGED*): *AGED* is used to evaluate the potential effects of the specific activities of ^{238}U, ^{232}Th and ^{40}K on certain important organs of the body, such as reproductive organs (gonads), bone marrow and bone cells. According to Shams *et al,* 2015;

$$AGDE(\mu Sv/y) = 3.09A_{Ra} + 4.18A_{Th} + 0.314A_{K}$$

Where A_{Ra}, A_{Th} and A_{K} are the specific activities of ^{238}U, ^{232}Th and ^{40}K respectively, while the coefficients 3.09, 4.18 and 0.314 are the respective conversion factors. Each organ of the body responds differently to ionizing radiation.

RESULTS

Data on the radionuclide concentrations of ^{40}K, ^{238}U and ^{232}Th collected from the sand-mining field across twelve different locations are presented in Table 1. The size of each location determines the number of readings to be taken. The data were then analyzed to determine their respective activity concentration, absorbed dose rate (indoor and outdoor), radium equivalent (Ra_{eq}), hazard indices (internal and external), annual effective dose equivalent (indoor and outdoor), excess life cancer risk (indoor and outdoor), annual gonadal equivalent dose and the representative level index, which were presented in Table 2.3.1 Radionuclide Concentrations

Table 1: Distribution of radionuclide concentrations from different major sand-mining locations within Jos and its environs.

GPS Coordinates					Radionuclide Concentration			
S/N	LOCATION	Latitude ^{0}N	Longitude ^{0}E	ELV. (m)	K (%)	^{238}U (ppm)	^{232}Th (ppm)	Dose (nGy/h)
1	Gero	09 49 27.9	008 48 47.1	1175	1.4	10	19.7	152
2	Gero	09 49 27.1	008 48 47.5	1171	1	6.1	29.2	151.6
3	Gero	09 49 26.8	008 48 48.5	1174	0.9	9.8	25.7	162.6
4	Gero	09 49 26.8	008 48 48.5	1172	1.7	10.1	33.1	201.6
5	Gero	09 49 26.5	008 48 48.3	1173	1.1	7.3	29.3	160.9
6	Gero	09 49 26.3	008 48 48.0	1175	1.2	6.2	30.4	157.9
7	Gero	09 49 25.9	008 48 47.6	1174	1.2	5.1	26.8	140.4
8	Gero	09 49 25.5	008 48 47.3	1177	1.1	7.4	27.6	156.4
9	Gero	09 48 39.0	008 47 12.8	1156	0.4	6	19.2	108.1
10	Gero	09 48 39.4	008 47 13.1	1154	0.4	5.5	16.8	96.9
11	Gero	09 48 39.8	008 47 13.1	1157	0.5	9.9	31.1	174.6
12	Dogo Na-Hauwa	09 48 37.8	008 57 10.9	1227	1.5	11.6	30.5	199.8
13	Dogo Na-Hauwa	09 48 38.4	008 57 10.9	1228	0.8	10	25.5	161.9
14	Dogo Na-Hauwa	09 48 38.8	008 57 10.5	1228	0.7	4.9	22.9	118.4
15	Dogo Na-Hauwa	09 48	008 57	122	0.9	6.9	22.8	133.5

		39.2	10.4	9				
16	Dogo Na-Hauwa	09 48 39.9	008 57 10.8	1230	1.2	11.2	29.5	188.2
17	Dogo Na-Hauwa	09 48 40.4	008 57 10.1	1230	1	11	26.1	173.5
18	Dogo Na-Hauwa	09 48 40.9	008 57 09.9	1233	2	11.2	32	208.8
19	Dogo Na-Hauwa	09 48 41.5	008 57 09.9	1237	1.2	7.4	26.7	155.1
20	Dogo Na-Hauwa	09 48 42.2	008 57 09.8	1237	1.1	6.8	31.3	163.3
21	Dogo Na-Hauwa	09 48 42.1	008 57 09.1	1236	0.6	8.5	15.4	115.7
22	Lejengre	09 47 32.6	008 56 10.8	1253	0.8	7.1	22.8	133.8
23	Lejengre	09 47 32.4	008 56 10.8	1253	0.7	12.5	28.4	186.5
24	Lejengre	09 47 32.5	008 56 11.0	1252	0.9	12.1	36.5	213
25	Lejengre	09 47 31.7	008 56 11.4	1256	1.5	8.1	26.6	164.3
26	Lejengre	09 47 31.8	008 56 11.6	1254	1	9	26.8	161.7
27	Lejengre	09 47 32.3	008 56 12.6	1253	1.2	11.3	25.6	176.5
28	Lejengre	09 47 36.6	008 56 12.5	1258	1.2	12.7	17.3	191.9
29	Lejengre	09 47 36.9	008 56 12.7	1257	1.1	9.4	37.9	202.6
30	DU (Behind Jonah Jang House)	09 46 19.5	005 53 03.1	1280	1.8	9.1	38.7	214.5
31	DU (Behind Jonah Jang House)	09 46 19.2	008 53 02.6	1277	1.1	13	34.5	215
32	DU (Behind Jonah Jang House)	09 46 18.9	008 53 02.3	1277	1.1	7.2	28.1	156.5
33	DU (Behind Jonah Jang House)	09 46 17.1	008 53 02.4	1276	0.9	7.4	27.6	152.7
34	DU (Behind Jonah Jang House)	09 46 16.4	008 53 01.6	1269	2.3	10.3	33.9	214.1
35	DU (Behind Jonah Jang House)	09 46 16.9	008 53 00.6	1268	1.2	12	31.4	200.4
36	DU (Behind Jonah Jang House)	09 46 17.3	008 53 00.1	1266	1.5	12.8	30.4	206.9
37	DU (Behind Jonah Jang House)	09 46 18.0	008 53 59.7	1273	1.5	9.1	28.7	177.8
38	DU (Behind Jonah Jang House)	09 46 18.8	008 53 59.2	1270	0.9	7.3	17.9	120.7
39	DU (Behind Jonah Jang House)	09 46 19.6	008 52 59.4	1271	0.7	6.3	17.3	108.7
40	Bitsichi	09 43 05.3	008 55 11.0	1212	2.1	12.2	36.5	232
41	Bitsichi	09 43 05.5	008 55 10.7	1214	10.1	34.7	136.3	832
42	Bitsichi	09 43 05.3	008 55 11.0	1211	0.8	10.5	14.3	127.3

43	Bitsichi	09 43 05.6	008 55 11.1	121 3	0.9	8.8	20	144.4
44	Bitsichi	09 43 05.1	008 55 10.2	121 3	0.4	11.3	17.6	138.6
45	Bitsichi	09 43 04.7	008 55 10.7	121 4	1.8	19.2	33.4	263.2
46	Bitsichi	09 43 04.6	008 55 10.4	121 3	0.7	10.8	25	163.4
47	Bitsichi	09 43 04.7	008 55 10.2	121 5	1.1	15.5	22	191.2
48	Bitsichi	09 43 04.9	008 55 09.9	121 3	0.8	9.7	11.4	108.7
49	Bitsichi	09 43 05.1	008 55 09.8	121 3	0.2	9.5	10.7	100.4
50	Bitsichi	09 43 04.7	008 55 09.7	121 5	0.8	14.9	32.9	218.6
51	Bitsichi	09 43 10.8	008 55 09.1	121 2	0.5	12.3	40.3	120.6
52	Rayfield Resort	09 50 17.8	008 54 59.3	130 2	5.1	0.4	0.3	38.8
53	Rayfield Resort	09 50 17.8	008 54 59.1	130 1	10.6	1.7	1.4	183.5
54	Rayfield Resort	09 50 17.8	008 54 59.0	130 2	5.4	0.3	0.9	90.4
55	Rayfield Resort	09 50 16.7	008 54 59.3	130 3	9	1	0.8	151.4
56	Rayfield Resort	09 50 16.4	008 54 59.1	130 2	7.5	0.8	0.7	125.8
57	Rayfield Resort	09 50 16.6	008 54 59.2	130 4	5.3	0.6	0.6	89.4
58	Rayfield Resort	09 50 16.5	008 54 58.8	130 4	4.1	0.2	0.3	66.5
59	Rayfield Resort	09 50 17.0	008 54 57.9	130 1	5.1	0.5	0.3	85.1
60	Rayfield Resort	09 50 17.4	008 55.01	129 8	4.9	0.3	0.3	79.5
61	Bukuru Low-Cost Bridge	09 49 05.7	008 52 05.7	123 0	1.4	8.4	28.6	170.7
62	Bukuru, Bhd Govt. House	09 48 46.0	008 53 10.1	126 7	1.7	7.8	31.5	180.8
63	Bukuru, Bhd Govt. House	09 48 46.2	008 53 08.1	126 8	1.8	6	32.9	175.1
64	Bukuru, Bhd Govt. House	09 48 50.3	008 53 08.1	126 2	2	7.9	25.5	167.3
65	Bukuru, Bhd Govt. House	09 48 52.9	008 53 10.3	125 9	1.5	7.3	28.2	163.1
66	Bukuru, Bhd Govt. House	09 48 50.8	008 53 12.2	125 6	1.9	8	26.2	168.3
67	Bukuru, Bhd Govt. House	09 48 50.0	008 53 11.4	126 1	1.7	9.5	27.1	177
68	Gold & Base	09 52 44.1	008 54 41.5	123 2	1.6	7.7	26.9	163
69	Gold & Base	09 52 42.6	008 54 40.8	123 6	1.9	8.8	26.6	172.2
70	Stream Channel,	09 52	008 51	125	1.5	7.6	30.6	173.1

	Amusement Park	44.5	56.3	5				
71	Stream Channel, Amusement Park	09 52 32.4	008 51 46.7	126 3	2.2	9.5	26.8	184.4
72	Mazah	09 58 48.3	008 57 09.6	939	1.8	6	29.3	163.9
73	Mazah	09 58 49.2	008 57 10.9	941	1.7	8.2	28.4	173.1
74	Mazah	09 58 44.2	008 56 38.1	948	1.8	5.6	32.2	170.1
75	Busa-Buji Bridge	09 56 37.0	008 52 19.4	113 0	1.7	7.7	29.6	173.7
76	Busa-Buji Bridge	09 56 36.1	008 52 18.9	113 2	2	6.8	29.9	174.1
77	Odus	09 57 31.8	008 54 45.3	121 5	2.1	5.6	21.3	138.7
78	Odus	09 57 33.8	008 54 45.6	122 1	2.4	5.6	20.1	141.3

A contour map was produced, showing the concentration of uranium (238U), thorium (232Th) and potassium (40K) as varied from one location to another. Areas around the red background are areas with higher radiation concentration while the areas around the blue background are the areas with lower radiation concentration.

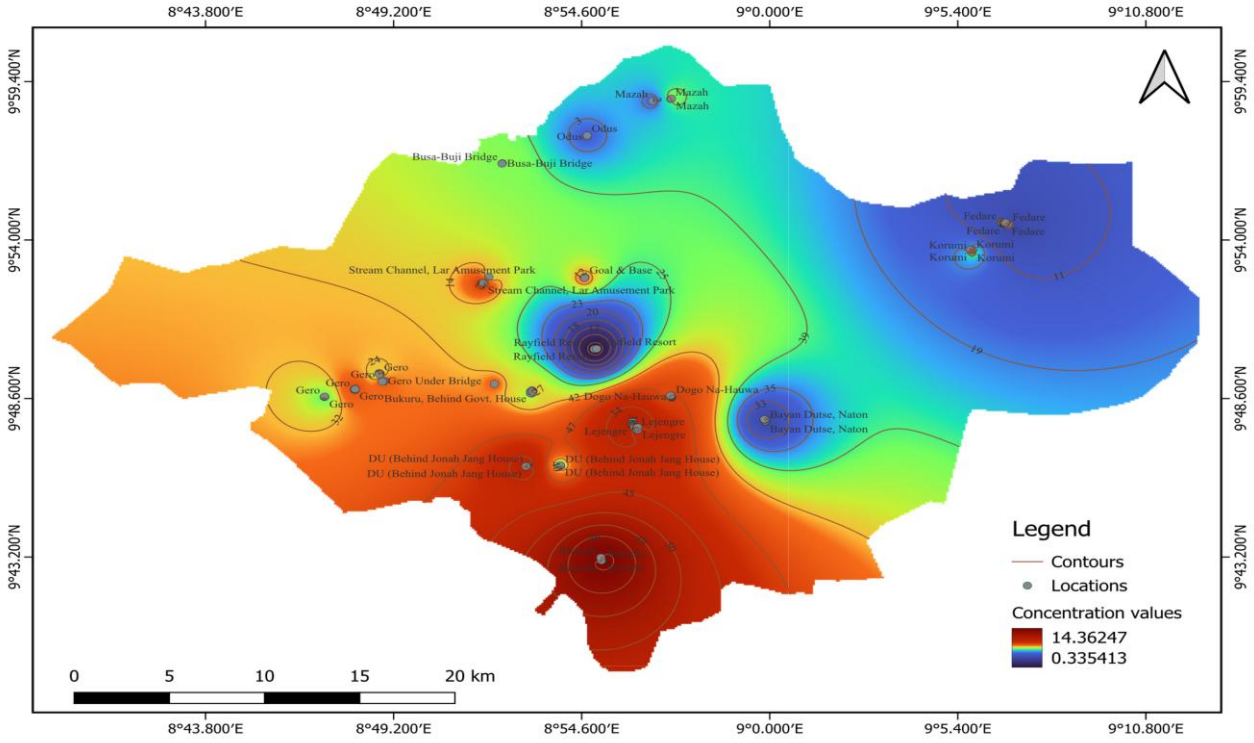


Figure 1: Uranium (^{238}U) Concentration within the sand mining area

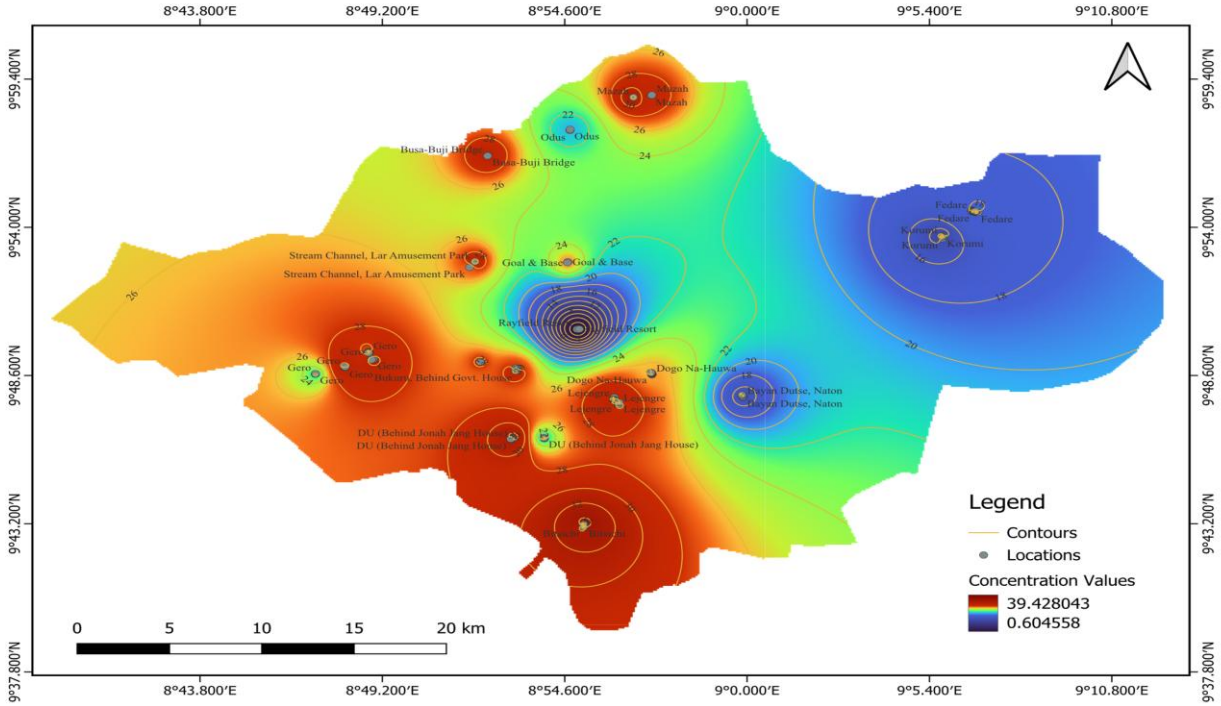


Figure 2: Thorium (^{232}Th) Concentration within the sand mining area

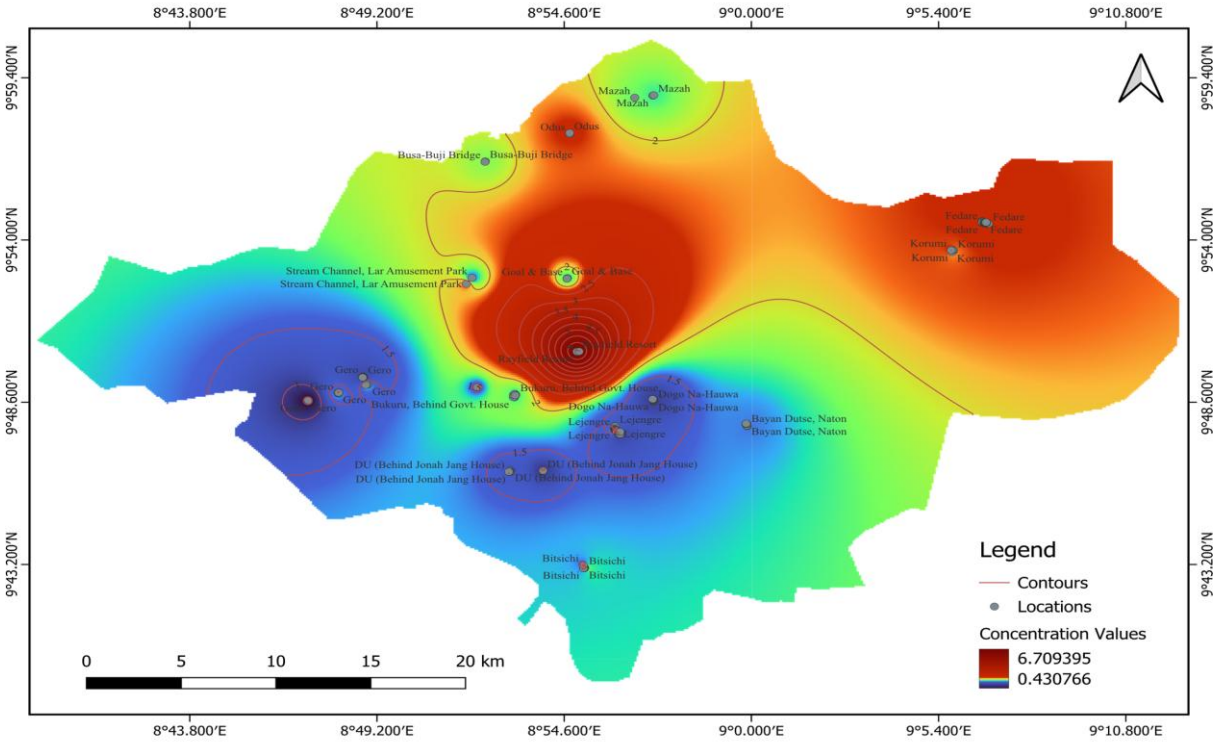


Figure 3: Potassium (^{40}K) concentration within the sand mining area

The concentration values recorded in Table 1 as captured from the field were thereafter converted into activity concentration. The annual effective dose equivalent, excess lifetime cancer risk, radium equivalent activity, internal and external hazard indices, annual gonadal equivalent dose and representative level index from the sand mining sites where all calculated and presented in Table 2.

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Table 2: Activity concentration of ^{40}K ^{238}U & ^{232}Th, annual effective dose equivalent, excess lifetime cancer risk, radium equivalent activity, internal & external hazard indices, annual gonadal equivalent dose and representative level index from the locations studied.

S/N	LOCATION	K (Bq/Kg)	U (Bq/kg)	Th (Bq/Kg)	D (nGy/h)	AEDE*in* (mSv/y)	AEDE*out* (mSv/y)	ELCR*in*	ELCR*out*	Ra*eq*, (Bq/Kg)	H*ex*	H*in*	*AGED* (µSv/y)	RLI
1	Gero	358.974	123.457	80.081	152.000	0.699	0.233	2.447	0.816	265.614	0.717	1.051	828.939	1.863
2	Gero	256.410	75.309	118.699	151.600	0.697	0.232	2.440	0.813	264.792	0.715	0.919	809.379	1.860
3	Gero	230.769	120.988	104.472	162.600	0.748	0.249	2.617	0.872	288.151	0.778	1.105	883.004	2.005
4	Gero	435.897	124.691	134.553	201.600	0.927	0.309	3.245	1.082	350.666	0.947	1.284	1084.599	2.467
5	Gero	282.051	90.123	119.106	160.900	0.740	0.247	2.590	0.863	282.163	0.762	1.006	864.907	1.980
6	Gero	307.692	76.543	123.577	157.900	0.726	0.242	2.542	0.847	276.951	0.748	0.955	849.687	1.951
7	Gero	307.692	62.963	108.943	140.400	0.646	0.215	2.260	0.753	242.444	0.655	0.825	746.553	1.714
8	Gero	282.051	91.358	112.195	156.400	0.719	0.240	2.517	0.839	273.515	0.739	0.986	839.836	1.919
9	Gero	102.564	74.074	78.049	108.100	0.497	0.166	1.740	0.580	193.581	0.523	0.723	587.338	1.343
10	Gero	102.564	67.901	68.293	96.900	0.446	0.149	1.560	0.520	173.457	0.469	0.652	527.483	1.204
11	Gero	128.205	122.222	126.423	174.600	0.803	0.268	2.810	0.937	312.879	0.845	1.175	946.370	2.165
	MINIMUM	**102.564**	**62.963**	**68.293**	**96.900**	**0.446**	**0.149**	**1.560**	**0.520**	**173.457**	**0.469**	**0.652**	**527.483**	**1.204**
	MAXIMUM	**435.897**	**124.691**	**134.553**	**201.600**	**0.927**	**0.309**	**3.245**	**1.082**	**350.666**	**0.947**	**1.284**	**1084.599**	**2.467**
	AVERAGE	**254.079**	**93.603**	**106.763**	**151.182**	**0.695**	**0.232**	**2.433**	**0.811**	**265.838**	**0.718**	**0.971**	**815.282**	**1.861**
12	Dogo Na-Hauwa	384.615	143.210	123.984	199.800	0.919	0.306	3.216	1.072	350.122	0.946	1.333	1081.540	2.451
13	Dogo Na-Hauwa	205.128	123.457	103.659	161.900	0.745	0.248	2.606	0.869	287.483	0.777	1.110	879.184	1.996
14	Dogo Na-Hauwa	179.487	60.494	93.089	118.400	0.545	0.182	1.906	0.635	207.432	0.560	0.724	632.399	1.454
15	Dogo Na-Hauwa	230.769	85.185	92.683	133.500	0.614	0.205	2.149	0.716	235.491	0.636	0.866	723.098	1.649
16	Dogo Na-Hauwa	307.692	138.272	119.919	188.200	0.866	0.289	3.029	1.010	333.448	0.901	1.274	1025.135	2.326
17	Dogo Na-Hauwa	256.410	135.802	106.098	173.500	0.798	0.266	2.793	0.931	307.266	0.830	1.197	943.630	2.137
18	Dogo Na-	512.821	138.272	130.081	208.800	0.960	0.320	3.361	1.120	363.775	0.983	1.356	1132.025	2.565

NABDA
Journal of Biotechnology Research
ISSN: 1119-0531
Special Issue Vol. 5(2): (2026)

	Hauwa													
19	Dogo Na-Hauwa	307.692	91.358	108.537	155.100	0.713	0.238	2.497	0.832	270.258	0.730	0.977	832.595	1.900
20	Dogo Na-Hauwa	282.051	83.951	127.236	163.300	0.751	0.250	2.629	0.876	287.616	0.777	1.004	879.817	2.020
21	Dogo Na-Hauwa	153.846	104.938	62.602	115.700	0.532	0.177	1.862	0.621	206.305	0.557	0.841	634.242	1.428
	MINIMUM	**153.846**	**60.494**	**62.602**	**115.700**	**0.532**	**0.177**	**1.862**	**0.621**	**206.305**	**0.557**	**0.724**	**632.399**	**1.428**
	MAXIMUM	**512.821**	**143.210**	**130.081**	**208.800**	**0.960**	**0.320**	**3.361**	**1.120**	**363.775**	**0.983**	**1.356**	**1132.025**	**2.565**
	AVERAGE	**282.051**	**110.494**	**106.789**	**161.820**	**0.744**	**0.248**	**2.605**	**0.868**	**284.919**	**0.770**	**1.068**	**876.366**	**1.993**
22	Lejengre	205.128	87.654	92.683	133.800	0.615	0.205	2.154	0.718	235.986	0.637	0.874	722.677	1.648
23	Lejengre	179.487	154.321	115.447	186.500	0.858	0.286	3.002	1.001	333.231	0.900	1.317	1015.780	2.303
24	Lejengre	230.769	149.383	148.374	213.000	0.980	0.327	3.429	1.143	379.327	1.025	1.428	1154.257	2.633
25	Lejengre	384.615	100.000	108.130	164.300	0.756	0.252	2.645	0.882	284.241	0.768	1.038	881.753	2.004
26	Lejengre	256.410	111.111	108.943	161.700	0.744	0.248	2.603	0.868	286.643	0.774	1.075	879.228	2.001
27	Lejengre	307.692	139.506	104.065	176.500	0.812	0.271	2.841	0.947	312.011	0.843	1.220	962.681	2.176
28	Lejengre	307.692	156.790	70.325	191.900	0.883	0.294	3.089	1.030	281.047	0.759	1.183	875.056	1.954
29	Lejengre	282.051	116.049	154.065	202.600	0.932	0.311	3.261	1.087	358.080	0.967	1.281	1091.149	2.502
	MINIMUM	**153.846**	**87.654**	**70.325**	**129.400**	**0.595**	**0.198**	**2.083**	**0.694**	**230.365**	**0.622**	**0.862**	**701.893**	**1.602**
	MAXIMUM	**1666.667**	**180.247**	**181.301**	**260.700**	**1.199**	**0.400**	**4.196**	**1.399**	**451.089**	**1.218**	**1.688**	**1397.402**	**3.186**
	AVERAGE	**352.991**	**127.654**	**118.889**	**183.067**	**0.842**	**0.281**	**2.947**	**0.982**	**324.846**	**0.877**	**1.222**	**1002.247**	**2.275**
30	DU	461.538	112.346	157.317	214.500	0.986	0.329	3.453	1.151	372.848	1.007	1.311	1149.657	2.630
31	DU	282.051	160.494	140.244	215.000	0.989	0.330	3.461	1.154	382.761	1.034	1.468	1170.710	2.660
32	DU	282.051	88.889	114.228	156.500	0.720	0.240	2.519	0.840	273.952	0.740	0.980	840.702	1.923
33	DU	230.769	91.358	112.195	152.700	0.702	0.234	2.458	0.819	269.566	0.728	0.975	823.733	1.885
34	DU	589.744	127.160	137.805	214.100	0.985	0.328	3.446	1.149	369.632	0.998	1.342	1154.130	2.619
35	DU	307.692	148.148	127.642	200.400	0.922	0.307	3.226	1.075	354.369	0.957	1.358	1087.938	2.469
36	DU	384.615	158.025	123.577	206.900	0.952	0.317	3.330	1.110	364.356	0.984	1.411	1125.618	2.546
37	DU	384.615	112.346	116.667	177.800	0.818	0.273	2.862	0.954	308.794	0.834	1.138	955.584	2.172

NABDA
Journal of Biotechnology Research
ISSN: 1119-0531
Special Issue Vol. 5(2): (2026)

S/N	LOCATION	K (Bq/Kg)	U (Bq/kg)	Th (Bq/Kg)	D (nGy/h)	AEDE*in* (mSv/y)	AEDE*out* (mSv/y)	ELCR*in*	ELCR*out*	Ra*eq*, (Bq/Kg)	H*ex*	H*in*	*AGED* (µSv/y)	RLI
38	DU	230.769	90.123	72.764	120.700	0.555	0.185	1.943	0.648	211.946	0.572	0.816	655.097	1.482
39	DU	179.487	77.778	70.325	108.700	0.500	0.167	1.750	0.583	192.163	0.519	0.729	590.652	1.341
	MINIMUM	**179.487**	**77.778**	**70.325**	**108.700**	**0.500**	**0.167**	**1.750**	**0.583**	**192.163**	**0.519**	**0.729**	**590.652**	**1.341**
	MAXIMUM	**589.744**	**160.494**	**157.317**	**215.000**	**0.989**	**0.330**	**3.461**	**1.154**	**382.761**	**1.034**	**1.468**	**1170.710**	**2.660**
	AVERAGE	**333.333**	**116.667**	**117.276**	**176.730**	**0.813**	**0.271**	**2.845**	**0.948**	**310.039**	**0.837**	**1.153**	**955.382**	**2.173**
40	Bitsichi	538.462	150.617	148.374	232.000	1.067	0.356	3.734	1.245	404.254	1.092	1.499	1254.688	2.847
41	Bitsichi	2589.744	428.395	554.065	832.000	3.826	1.275	13.392	4.464	1420.118	3.835	4.993	4452.912	10.123
42	Bitsichi	205.128	129.630	58.130	127.300	0.585	0.195	2.049	0.683	228.551	0.617	0.968	707.950	1.582
43	Bitsichi	230.769	108.642	81.301	144.400	0.664	0.221	2.324	0.775	242.671	0.656	0.949	748.003	1.691
44	Bitsichi	102.564	139.506	71.545	138.600	0.637	0.212	2.231	0.744	249.713	0.675	1.052	762.336	1.714
45	Bitsichi	461.538	237.037	135.772	263.200	1.210	0.403	4.237	1.412	466.730	1.261	1.901	1444.896	3.246
45	Bitsichi	179.487	133.333	101.626	163.400	0.751	0.250	2.630	0.877	292.479	0.790	1.150	893.156	2.025
47	Bitsichi	282.051	191.358	89.431	191.200	0.879	0.293	3.078	1.026	340.962	0.921	1.438	1053.682	2.358
48	Bitsichi	205.128	119.753	46.341	108.700	0.500	0.167	1.750	0.583	201.816	0.545	0.869	628.155	1.399
49	Bitsichi	51.282	117.284	43.496	100.400	0.462	0.154	1.616	0.539	183.432	0.496	0.813	560.323	1.251
50	Bitsichi	205.128	183.951	133.740	218.600	1.005	0.335	3.519	1.173	390.993	1.056	1.553	1191.850	2.700
51	Bitsichi	128.205	151.852	163.821	120.600	0.555	0.185	1.941	0.647	395.988	1.070	1.480	1194.251	2.736
	MINIMUM	**51.282**	**108.642**	**43.496**	**100.400**	**0.462**	**0.154**	**1.616**	**0.539**	**183.432**	**0.496**	**0.813**	**560.323**	**1.251**
	MAXIMUM	**2589.744**	**428.395**	**554.065**	**832.000**	**3.826**	**1.275**	**13.392**	**4.464**	**1420.118**	**3.835**	**4.993**	**4452.912**	**10.123**
	AVERAGE	**431.624**	**174.280**	**135.637**	**220.033**	**1.012**	**0.337**	**3.542**	**1.181**	**401.476**	**1.084**	**1.555**	**1241.017**	**2.806**
52	Rayfield Resort	1307.692	4.938	1.220	38.800	0.178	0.059	0.625	0.208	107.374	0.290	0.303	430.972	0.917
53	Rayfield Resort	2717.949	20.988	5.691	183.500	0.844	0.281	2.954	0.985	238.408	0.644	0.700	942.076	2.009
54	Rayfield Resort	1384.615	3.704	3.659	90.400	0.416	0.139	1.455	0.485	115.551	0.312	0.322	461.506	0.984

55	Rayfield Resort	2307.692	12.346	3.252	151.400	0.696	0.232	2.437	0.812	194.688	0.526	0.559	776.357	1.653
56	Rayfield Resort	1923.077	9.877	2.846	125.800	0.579	0.193	2.025	0.675	162.023	0.437	0.464	646.259	1.376
57	Rayfield Resort	1358.974	7.407	2.439	89.400	0.411	0.137	1.439	0.480	115.536	0.312	0.332	459.802	0.980
58	Rayfield Resort	1051.282	2.469	1.220	66.500	0.306	0.102	1.070	0.357	85.162	0.230	0.237	342.830	0.730
59	Rayfield Resort	1307.692	6.173	1.220	85.100	0.391	0.130	1.370	0.457	108.609	0.293	0.310	434.787	0.925
60	Rayfield Resort	1256.410	3.704	1.220	79.500	0.366	0.122	1.280	0.427	102.191	0.276	0.286	411.055	0.874
	MINIMUM	**1051.282**	**2.469**	**1.220**	**38.800**	**0.178**	**0.059**	**0.625**	**0.208**	**85.162**	**0.230**	**0.237**	**342.830**	**0.730**
	MAXIMUM	**2717.949**	**20.988**	**5.691**	**183.500**	**0.844**	**0.281**	**2.954**	**0.985**	**238.408**	**0.644**	**0.700**	**942.076**	**2.009**
	AVERAGE	**1623.932**	**7.956**	**2.529**	**101.156**	**0.465**	**0.155**	**1.628**	**0.543**	**136.616**	**0.369**	**0.390**	**545.072**	**1.161**
61	Bukuru Low-Cost	358.974	103.704	116.260	170.700	0.785	0.262	2.748	0.916	297.597	0.804	1.084	919.130	2.093
62	Bukuru	435.897	96.296	128.049	180.800	0.831	0.277	2.910	0.970	312.970	0.845	1.106	969.671	2.213
63	Bukuru	461.538	74.074	133.740	175.100	0.805	0.268	2.818	0.939	300.861	0.813	1.013	932.844	2.139
64	Bukuru	512.821	97.531	103.659	167.300	0.769	0.256	2.693	0.898	285.250	0.770	1.034	895.689	2.029
65	Bukuru	384.615	90.123	114.634	163.100	0.750	0.250	2.625	0.875	283.666	0.766	1.010	878.421	2.004
66	Bukuru	487.179	98.765	106.504	168.300	0.774	0.258	2.709	0.903	288.579	0.779	1.046	903.347	2.048
67	Bukuru	435.897	117.284	110.163	177.000	0.814	0.271	2.849	0.950	308.381	0.833	1.150	959.759	2.174
	MINIMUM	**384.615**	**74.074**	**103.659**	**163.100**	**0.750**	**0.250**	**2.625**	**0.875**	**283.666**	**0.766**	**1.010**	**878.421**	**2.004**
	MAXIMUM	**512.821**	**117.284**	**133.740**	**180.800**	**0.831**	**0.277**	**2.910**	**0.970**	**312.970**	**0.845**	**1.150**	**969.671**	**2.213**
	AVERAGE	**452.991**	**95.679**	**116.125**	**171.933**	**0.791**	**0.264**	**2.768**	**0.923**	**296.618**	**0.801**	**1.060**	**923.289**	**2.101**
68	Goal & Base	410.256	95.062	109.350	163.000	0.750	0.250	2.624	0.875	283.021	0.764	1.021	879.643	2.001

69	Goal & Base	487.179	108.642	108.130	172.200	0.792	0.264	2.772	0.924	300.781	0.812	1.106	940.662	2.130
	MINIMUM	**410.256**	**95.062**	**108.130**	**163.000**	**0.750**	**0.250**	**2.624**	**0.875**	**283.021**	**0.764**	**1.021**	**879.643**	**2.001**
	MAXIMUM	**487.179**	**108.642**	**109.350**	**172.200**	**0.792**	**0.264**	**2.772**	**0.924**	**300.781**	**0.812**	**1.106**	**940.662**	**2.130**
	AVERAGE	**448.718**	**101.852**	**108.740**	**167.600**	**0.771**	**0.257**	**2.698**	**0.899**	**291.901**	**0.788**	**1.064**	**910.152**	**2.066**
70	Amusement Park	384.615	93.827	124.390	173.100	0.796	0.265	2.786	0.929	301.321	0.814	1.067	930.646	2.126
71	Amusement Park	564.103	117.284	108.943	184.400	0.848	0.283	2.968	0.989	316.508	0.855	1.172	994.918	2.247
	MINIMUM	**384.615**	**93.827**	**108.943**	**173.100**	**0.796**	**0.265**	**2.786**	**0.929**	**301.321**	**0.814**	**1.067**	**930.646**	**2.126**
	MAXIMUM	**564.103**	**117.284**	**124.390**	**184.400**	**0.848**	**0.283**	**2.968**	**0.989**	**316.508**	**0.855**	**1.172**	**994.918**	**2.247**
	AVERAGE	**474.359**	**105.556**	**116.667**	**178.750**	**0.822**	**0.274**	**2.877**	**0.959**	**308.915**	**0.834**	**1.120**	**962.782**	**2.187**
72	Mazah	461.538	74.074	119.106	163.900	0.754	0.251	2.638	0.879	279.934	0.756	0.956	871.674	1.993
73	Mazah	435.897	101.235	115.447	173.100	0.796	0.265	2.786	0.929	299.888	0.810	1.084	932.256	2.120
74	Mazah	461.538	69.136	130.894	170.100	0.782	0.261	2.738	0.913	291.853	0.788	0.975	905.691	2.078
	MMINIMUM	**435.897**	**69.136**	**115.447**	**163.900**	**0.754**	**0.251**	**2.638**	**0.879**	**279.934**	**0.756**	**0.956**	**871.674**	**1.993**
	MAXIMUM	**461.538**	**101.235**	**130.894**	**173.100**	**0.796**	**0.265**	**2.786**	**0.929**	**299.888**	**0.810**	**1.084**	**932.256**	**2.120**
	AVERAGE	**452.991**	**81.481**	**121.816**	**169.033**	**0.777**	**0.259**	**2.721**	**0.907**	**290.558**	**0.785**	**1.005**	**903.207**	**2.063**
75	Busa-Buji Bridge	435.897	95.062	120.325	173.700	0.799	0.266	2.796	0.932	300.691	0.812	1.069	933.572	2.128
76	Busa-Buji Bridge	512.821	83.951	121.545	174.100	0.801	0.267	2.802	0.934	297.247	0.803	1.030	928.490	2.117
	MINIMUM	**435.897**	**83.951**	**120.325**	**173.700**	**0.799**	**0.266**	**2.796**	**0.932**	**297.247**	**0.803**	**1.030**	**928.490**	**2.117**
	MAXIMUM	**512.821**	**95.062**	**121.545**	**174.100**	**0.801**	**0.267**	**2.802**	**0.934**	**300.691**	**0.812**	**1.069**	**933.572**	**2.128**
	AVERAGE	**474.359**	**89.506**	**120.935**	**173.900**	**0.800**	**0.267**	**2.799**	**0.933**	**298.969**	**0.807**	**1.049**	**931.031**	**2.122**
77	Odus	538.462	69.136	86.585	138.700	0.638	0.213	2.233	0.744	234.414	0.633	0.820	744.633	1.686
78	Odus	615.385	69.136	81.707	141.300	0.650	0.217	2.274	0.758	233.362	0.630	0.817	748.397	1.688
	MINIMUM	**538.462**	**69.136**	**81.707**	**138.700**	**0.638**	**0.213**	**2.233**	**0.744**	**233.362**	**0.630**	**0.817**	**744.633**	**1.686**
	MAXIMUM	**615.385**	**69.136**	**86.585**	**141.300**	**0.650**	**0.217**	**2.274**	**0.758**	**234.414**	**0.633**	**0.820**	**748.397**	**1.688**
	AVERAGE	**576.923**	**69.136**	**84.146**	**140.000**	**0.644**	**0.215**	**2.254**	**0.751**	**233.888**	**0.632**	**0.819**	**746.515**	**1.687**

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DISCUSSION

The concentrations of radionuclides of interest as well as their specific activity varied from one location to another as a result of the difference in environment and the source rocks from which the sand material used for the construction came from. Though the results shows that the background doses from most of the areas studied were within the permissible limits, however, there are few points within each of location where anomalous values were recorded with some emitting radiation above the 1mSv/y WHO recommended public safety value. The radiological indices recorded across the entire area of studies are as follows; Radium Equivalent Activity (85.162Bq/Kg – 1420.118Bq/Kg) with areas around Rayfield having lower values while Bitsichi axis have the highest activity with values far above 370Bq/Kg permissible value.

The average absorbed dose rate rate recorded ranges between 38.8nGy/h – 832nGy/h as shown in table 2, the average annual effective dose equivalent $AEDE_{indoor}$ recorded across area of study falls within the range of 0.465-1.012 $mSvy^{-1}$ while average $AEDE_{outdoor}$ recorded was between 0.11-0.28 $mSvy^{-1}$ as seen in table 2, The average values for excess lifetime cancer risk obtained across study area range between 1.628 $x\,10^{-3}$ – 3.542 $x\,10^{-3}$ (indoor) and 0.543 $x\,10^{-3}$ – 1.181 $x\,10^{-3}$ (outdoor) which was by far above the reference value of $0.29x10^{-3}$ set (Aziz *et al.* 2014) with the Bitsichi sand having the worst ELCR values. The annual gonadal equivalent dose, *AGED* which is the evaluation of the potential effects of the specific activities of ^{238}U, ^{232}Th and ^{40}K on certain important organs of the body, such as reproductive organs (gonads), bone marrow and bones cells ranged between 342.830 uSv/y – 4452.912 uSv/y.

CONCLUSION

At the end of this study, background radiation values for different locations were assessed. With the use of BGO (Bismuth Germanate Oxide) Gamma Super Spectrometer RS-230, the distribution of radionuclides concentration and the activity concentration of ^{238}U, ^{232}Th and ^{40}K across locations studied within Jos and its environs were determined. Radiological parameters and indices such as radium equivalent activity, internal and external hazard, absorbed dose rate, annual effective dose equivalent, excess life cancer risk, annual gonadal equivalent dose and representative level index were all determined. The radionuclides concentration data collected were analyzed to determine their possible impact. Some of the areas studied indicated lower radiation dose values while other locations show slightly higher to extremely higher background values indicating the role geological materials played across these different locations.

RECOMMENDATION

1. Some radioactive particles like thorites are sand size particles and can be found anywhere, mostly in soil. Therefore, background radiation assessment for all BIODEC centres should be carried out in order to determine these radiological indices; radium equivalent activity, internal and external hazard, absorbed dose rate, annual effective dose equivalent, excess life cancer risk and the annual gonadal equivalent dose. This will ensure the safety of staffs, laboratories, plants and animal's resource breeding within the centre and genetic engineered products.
2. Sensitization on the impact of ionizing radiation to life should be carried out periodically to keep update on the current global trend.

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