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Assessment of Outdoor Gamma Exposure Levels at some Borehole and Well Sites in Dutse, Nigeria

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Abstract

The lives on the earth are continuously exposed to ionizing radiation originating mainly from natural sources. Fortunately, the associated health hazard is not an acute problem globally. However, health complications are inevitable in areas assumed to have high background ionizing radiation levels. The present study aims to unveil the scenarios of outdoor gamma radiation levels at Dutse, the northwestern part of Nigeria. In this study, gamma exposure levels (GEL) across sixty-six (66) selected boreholes and local wells located in the said region have been measured using a well-calibrated hand dosimeter (Radiation Alert Inspector). Using the GEL values some significant radiation parameters were calculated to determine the possibility of radiological health risks to the local people. The measured

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gamma exposure level around the boreholes is seen to vary from 1.1 - 1.9 µrem/hr with a mean of 1.5 µrem/hr and around the wells it ranges between 1.1 – 1.8 µrem/hr with a mean of 1.5 µrem/hr. For boreholes, the estimated annual effective dose (AED) varies between 13.50 – 23.31 µSv/yr with a mean of 17.29 µSv/yr and for wells the same resulted 13.50 – 22.08 µSv/yr with a mean of 17.92 µSv/yr. All the obtained dose values are lower than the UNSCEAR proposed world average level of 70 µSv/yr. The estimated average ELCR values was found to be 0.061 × 10^{-3} and 0.064 × 10^{-3} for boreholes and wells respectively. All findings were below the UNSCEAR recommended world average level of (0.29 × 10^{-3}). In summary, this work indicates a low risk of exposure to outdoor ionizing radiation among the inhabitants around the study locations.

Keywords: Ionizing Radiation, Gamma Exposure Level, Annual Effective Dose, Dutse, Cancer Risk

INTRODUCTION

Human beings are exposed daily to natural radioactivity due to presence of several radionuclides everywhere on the planet earth like rocks, soil, water and air (Atwood 2013). Depending on the source, these naturally occurring radioactive elements may be categorized into three types: primordial, cosmogenic and anthropogenic. The Primordial radionuclides riginated before the creation of the earth and are present mainly in the earth's crust (Dragović *et al*. 2006; Atwood 2013). Cosmogenic radioactivity is formed as a consequence of cosmic ray interactions. Residents of high-altitude regions may be affected significantly by cosmic radiation (Mohanty *et al*. 2004). The radioactivity originated as a consequence of human activities is termed as anthropogenic which are minor in amounts compared to the natural ones (Atwood 2013). This includes cesium (^{137}Cs) resulting from the fallout from weapons testing and the Chernobyl accident (Shahbazi-Gahrouei *et al.* 2013). All these radioactive elements can be sources of both internal and external radiation exposures (UNSCEAR 2000; Shahbazi-Gahrouei *et al*. 2013; Atwood 2013). The lithological separation of each location and the geological formation of the rock from which the soils in each area were formed determine the natural ambient radioactivity and the related radiation exposure (UNSCEAR 2000; Tzortzis *et al*. 2004).

Approximately 80% of all radiation exposure in the general population is caused by naturally occurring radiation. The majority of which is produced by the radioactive decay of primordial radionuclides thorium (^{232}Th), uranium (^{238}U) and also potassium (^{40}K) (UNSCEAR 2000; Ramachandran 2011), present in varying quantities everywhere (El-Arabi *et al.* 2007). The radiation exposure is influenced by a variety of variables, including changes in sea level, the type of geological, and the geographical environment (Chiozzi *et al*. 2002; Dragović *et al*. 2006). This causes unregulated environmental radiation exposure and increases the ionising radiation dosage in the population (Kamal *et al.* 2013). Hence, investigating radiation levels and the risks they pose is of utmost relevance (Ajani *et al*. 2020; Garba *et al*. 2021). Long-term exposure to ultra-high radiation levels can result in tumors and other illnesses, which is a serious threat to people's health (Liu *et al*. 2020).

So far, several studies with different aims, techniques and sampling methods have been carried out to assess the contamination level of water in the selected study locations of Dutse, Nigeria. A research was carried out by Abdullahi *et al*. (2016) to measure the concentration of heavy metals and gross alpha and beta radioactivity in drinking water collected from local wells and boreholes of Dutse town in north-west of Nigeria. This study revealed that the concentrations of heavy metals like Iron (Fe), Manganese (Mn) and Mercury (Hg) have exceeded the maximum contamination level set by WHO and NSDWQ for safe drinking water. For all well water samples both the measured gross alpha and beta radioactivity have exceeded the WHO proposed maximum recommended level, whereas for borehole water samples the measured gross beta radioactivity have crossed the reference limit. The overall results showed that many of the sampling areas are not suitable for agriculture, drinking and other domestic activities. They recommended that more studies should be carried out to ensure the safety of the general public in these locations. The research work of Chifu *et al.* (**2016**) determined the gross alpha and beta radioactivity in drinking water collected from Dutse Town, Nigeria and estimated the corresponding annual effective dose of the samples for all age categories. The findings suggested that a significant number of the sample sites are contaminated with radioactive substances. Consequently, it is advisable to either arrange for a different water source or subject the water from these locations to treatment before utilizing it for household purposes and consumption. In their study, Dankawu *et al.* (**2021**) determined the radon activity and the annual effective dose due to ingestion of radon containing water for some boreholes and wells water sample in Dutse at Jigawa State of Nigeria. The study indicated that the radon activitiy of most of the samples have exceeded the WHO proposed reference limit. Also, the annual effective dose due to consumption of water from all the samples exhibited high dose values with respect to the WHO proposed reference dose limit. The study of Dankawu *et al.* (***2021***) also revealed that the estimated excess lifetime cancer risk (ELCR) values for all of the samples have exceeded the UNSCEAR proposed world average limit. They concluded that, in terms of radiology this study suggests that the water resources in the Dutse area are unsuitable for drinking and domestic use. They have also recommended that the water under this study area should be to examine before use.

Despite numerous studies on measurement of gross alpha and beta radioactivity levels, presence of heavy metals and radon in drinking water, no research was done to find out the amount of background radiation in Dutse, a city in the northwest of Nigeria. The present study aims to evaluate the level of exposure to gamma radiation in selected boreholes and local wells locations in Dutse. Annual effective dose and lifetime cancer risk linked to gamma radiation exposure will also be determine. Going forward, this study could serve as a basis for further inquiries into the possible hazards of natural radiation in the surrounding area.

MATERIALS AND METHODS

Study area

Dutse is the capital city of Jigawa State, located in northern Nigeria. It holds the title of the largest city with an area of approximately 1099.60 km^2 and an estimated population of 365,818 in 2015 (Ogunleye *et al.* 2018). The name "Dutse," formerly known as "Dutsi," is derived from the Hausa word for rock reflecting the rocky topography of this area. These rocks are mainly igneous in nature. The geology of the place also exhibits sedimentary rocks, which were formed from the deposition of sediments and organic materials over millions of years. The sedimentary rocks in the area are part of the Chad Formation, which is a geological unit that extends across the Sahel region of Africa. The Chad Formation is made up of sandstones, shales, and clays, which were deposited during the Cretaceous and Tertiary periods (Dutse 2022). The sandstones in the Chad Formation are particularly important, as they form the aquifers that provide water for the region. These aquifers are recharged by rainfall and are an important resource for agriculture and domestic use. In addition to the Chad Formation, there are also some volcanic rocks in the Dutse area. These rocks were formed by volcanic activity during the Cretaceous period and are primarily composed of basalt and andesite (Dutse 2022). Overall, the geology of Dutse is dominated by sedimentary rocks, which are important for both their groundwater resources and their potential for oil and gas exploration. The volcanic rocks in the area also provide insights into the geological history of the region.

Therefore, based on the geological features observed in the study area, it can be inferred that there is a possibility of the presence of high background radiation (Dragović *et al.* 2006).

Sampling and method of data collection

A total of sixty-six (66) sample location, which are mainly drinking water sources (Boreholes and Wells) for the local people, have been randomly selected across different wards under Dutse North Western Part Nigeria.

Farming is a major occupation among the Dutse people. Due to the lack of rainfall in summer, the local people are mainly dependent on these two water sources for drinking, household uses as well as cultivating their farmlands. For these reasons, we have chosen the two sources of water (boreholes and wells) for this study to know the background gamma exposure level. The study has been carried out during the summer season and all the readings have been taken between March to early October, 2022 around 12:00 noon and 3:00 pm in the afternoon. Locations of the sample collection sites are depicted in **Fig. 1**.

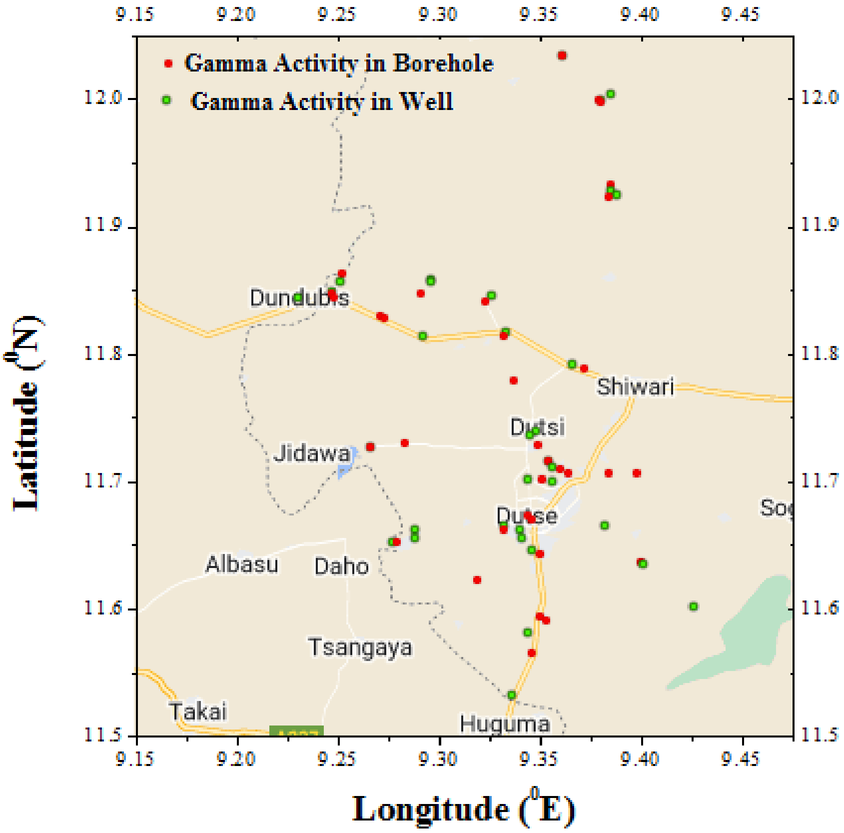

Fig. 1 Location of the sampling sites

The ambient gamma exposure has been measured using Radiation Alert Inspector (RAI) meter. The radiation meter is well calibrated and the calibration has been established at the reference conditions. The detector has been positioned at a height of one meter (1m) above the designated spots surrounding the sample locations throughout the measurement process (Baeza *et al*. 1994; Oyeyinka *et al.* 2012; Sharma *et al*. 2014). The Gamma exposure level has been measured and recorded for each selected point. Also, to know the actual location, the coordinates (latitude and longitude) of each of the sampling sites have been recorded using a Global Positioning System (GPS) meter.

Working principle of the Radiation Alert Inspector (RAI)

The Geiger-Muller (GM) counter is an integral part of the RAI meter (**Rilwan et al. 2022**), utilized for measuring background radiation. This GM counter operates based on the principle of ionization of gases caused by radiation. The counter comprises a cylindrical metal tube containing a gas and a 'window' made of a penetrable material (such as paper) that allows the entry of alpha, beta, or gamma rays. The tube has a wire at its centre, connected to one terminal of a direct current source, while the metal cylinder is connected to the other terminal. Ionizing radiation generates ions and electrons, leading to the conduction of an electric current. When, incoming radiation produces ions, they flow between the wire and metal cylinder, creating a current pulse. The counter amplifies these pulses, counts them, and displays the measured background radiation amount on a digital screen (**Atsue and Adegboyega 2017**).

Radiation Hazard Indices

To understand the possible public health risks, several types of gamma radiation doses have been calculated. The measured gamma exposure levels (GEL) is used to calculate Absorbed Dose (D) and Annual Effective Dose (AED). Also, Exc ess Lifetime Cancer Risk (ELCR) will be determined in order to know the chance of occurrence of cancer in a whole life. The dose values and the ELCR values are estimated using the following equations (Dankawu *et al.*, 2022; Sharma *et al.* 2014; Rilwan *et al.* 2022):

$$1\ \mu Sv/hr = 10^3\ nGy/hr \quad (1)$$

$$E\ (\mu Svy^{-1}) = D \times T \times OF \times CC \times 10^6 \quad (2)$$

$$ELCR = E \times DL \times RF \quad (3)$$

where, D = Absorbed dose (µGy/hr), AED = Annual effective dose (µSv/yr), T = The time of exposure per year by an individual in radiation field (365 × 24 = 8760 hours), OF = The outdoor occupancy factor (0.2 is taken as OF, UNSCEAR, 2000), CC = The conversion coefficient factor (0.7 Sv/Gy, UNSCEAR 2000; Mohanty *et al.* 2004; Sharma *et al.* 2014), DL = The average duration of life by an individual (70 years, UNSCEAR 2000; ICRP 2010) and RF are the Risk Factor (0.05 Sv^{-1}, ICRP 2010).

RESULT AND DISCUSSION

The ionizing background radiation in drinking water source locations (boreholes and wells) from thirty-three (33) wards across Dutse, Nigeria, have been studied. The obtained gamma exposure levels and their corresponding Absorb Dose, Annual Effective Dose and Excess Lifetime Cancer Risk have been presented in **Table 1**.

Table 1: Gamma exposure level (GEL) with the corresponding Absorb Dose (D), Annual Effective Dose (AED) and Excess Lifetime Cancer Risk (ELCR) across some selected borehole and wells in the study area

Borehole							
Sample Id	**Latitude (˚N)**	**Longitude (˚E)**	**Altitude (m)**	**GEL (µrem/hr)**	**D (µGy/hr)**	**AED (µSv/yr)**	**ELCR (× 10^{-3})**
BHS – 1	11.7259	9.33363	431	1.4	0.014	17.17	0.061
BHS – 2	11.7254	9.35127	457	1.7	0.017	20.85	0.073
BHS – 3	11.7586	9.34012	445	1.5	0.015	18.40	0.065
BHS – 4	11.7558	9.33608	440	1.3	0.013	15.95	0.056
BHS – 5	11.6234	9.33465	440	1.6	0.016	19.63	0.069
BHS – 6	11.5827	9.32374	428	1.5	0.015	18.40	0.065
BHS – 7	11.6699	9.41255	436	1.2	0.012	14.72	0.052

BHS – 8	11.6413	9.44675	415	1.2	0.012	14.72	0.052
BHS – 9	11.8027	9.36391	419	1.1	0.011	13.50	0.048
BHS - 10	11.8238	9.31983	403	1.4	0.014	17.17	0.061
BHS - 11	11.9187	9.39119	393	1.3	0.013	15.95	0.056
BHS - 12	11.916	9.39488	394	1.2	0.012	14.72	0.052
BHS - 13	11.6845	9.24247	440	1.7	0.017	20.85	0.073
BHS - 14	11.692	9.25804	440	1.4	0.014	17.17	0.061
BHS - 15	11.8508	9.20079	426	1.6	0.016	19.63	0.069
BHS - 16	11.8583	9.20615	423	1.3	0.013	15.95	0.056
BHS - 17	11.9826	9.39013	386	1.6	0.016	19.63	0.069
BHS - 18	11.9789	9.38348	385	1.4	0.014	17.17	0.061
BHS - 19	11.6922	9.32916	439	1.5	0.015	18.40	0.065
BHS - 20	11.6952	9.31766	439	1.5	0.015	18.40	0.065
BHS - 21	11.8587	9.26848	404	1.9	0.019	23.31	0.082
BHS - 22	11.8575	9.26868	405	1.6	0.016	19.63	0.069
BHS - 23	12.0078	9.357	388	1.2	0.012	14.72	0.052
BHS - 24	11.8215	9.26222	409	1.3	0.013	15.95	0.056
BHS - 25	11.8472	9.17797	432	1.6	0.016	19.63	0.069
BHS - 26	11.6877	9.33081	444	1.2	0.012	14.72	0.052
BHS - 27	11.6866	9.25688	439	1.5	0.015	18.40	0.065
BHS - 28	11.6788	9.33706	440	1.1	0.011	13.50	0.048
BHS - 29	11.695	9.38648	445	1.4	0.014	17.17	0.061
BHS - 30	11.7349	9.35135	500	1.1	0.011	13.50	0.048
BHS - 31	11.7384	9.34815	514	1.3	0.013	15.95	0.056
BHS - 32	11.7484	9.22763	420	1.3	0.013	15.95	0.056
BHS - 33	11.8492	9.31014	401	1.6	0.016	19.63	0.069

Well

Sample Id	**Latitude (˚N)**	**Longitude (˚E)**	**Altitude (m)**	**GEL (µrem/hr)**	**D (µGy/hr)**	**AED (µSv/yr)**	**ELCR × 10^{-3}**
WS – 1	11.7023	9.33374	432	1.5	0.015	18.40	0.065
WS – 2	11.7298	9.36156	463	1.8	0.018	22.08	0.078
WS – 3	11.7388	9.34861	513	1.4	0.014	17.17	0.061
WS – 4	11.7331	9.35635	470	1.1	0.011	13.50	0.048
WS – 5	11.6099	9.33711	443	1.7	0.017	20.85	0.073
WS – 6	11.6343	9.34314	435	1.5	0.015	18.40	0.065
WS – 7	11.6768	9.34288	435	1.2	0.012	14.72	0.052
WS – 8	11.7298	9.4088	432	1.2	0.012	14.72	0.052
WS – 9	11.7926	9.32501	415	1.6	0.016	19.63	0.069
WS – 10	11.7995	9.37291	421	1.7	0.017	20.85	0.073
WS – 11	11.7298	9.38928	447	1.3	0.013	15.95	0.056
WS – 12	11.9219	9.38995	392	1.2	0.012	14.72	0.052
WS – 13	11.7473	9.22768	418	1.6	0.016	19.63	0.069
WS – 14	11.7501	9.25057	420	1.4	0.014	17.17	0.061
WS – 15	11.8634	9.20834	423	1.8	0.018	22.08	0.078
WS – 16	11.8492	9.20149	426	1.5	0.015	18.40	0.065
WS – 17	11.9773	9.38322	384	1.1	0.011	13.50	0.048
WS – 18	11.9793	9.38257	386	1.5	0.015	18.40	0.065
WS – 19	11.6994	9.33736	440	1.3	0.013	15.95	0.056

WS – 20	11.6596	9.30053	450	1.4	0.014	17.17	0.061
WS – 21	11.8346	9.23382	414	1.6	0.016	19.63	0.069
WS – 22	11.8339	9.23658	409	1.7	0.017	20.85	0.073
WS – 23	11.9148	9.38943	392	1.4	0.014	17.17	0.061
WS – 24	11.8504	9.26116	402	1.2	0.012	14.72	0.052
WS – 25	11.8469	9.20277	425	1.6	0.016	19.63	0.069
WS – 26	11.6924	9.31803	442	1.4	0.014	17.17	0.061
WS – 27	11.6847	9.24436	440	1.2	0.012	14.72	0.052
WS – 28	11.6322	9.3471	430	1.7	0.017	20.85	0.073
WS – 29	11.6714	9.41154	436	1.8	0.018	22.08	0.078
WS – 30	11.7256	9.34424	457	1.3	0.013	15.95	0.056
WS – 31	11.7497	9.34179	450	1.5	0.015	18.40	0.065
WS – 32	11.8222	9.31717	405	1.6	0.016	19.63	0.069
WS – 33	11.8448	9.30586	404	1.4	0.014	17.17	0.061

From **Table 1** we can observe that the background gamma exposure level around the boreholes has varied from 1.1 - 1.9 µrem/hr with an average of 1.5 µrem/hr and around the wells it varies between 1.1 – 1.8 µrem/hr with an average of 1.5 µrem/hr**.**

To understand the impact of altitude of the sampling sites on their background radiation level, variation of gamma exposure levels with the corresponding altitude of the sampling sites (both for boreholes and wells) are plotted in **Fig. 2a** and **Fig. 2b**.

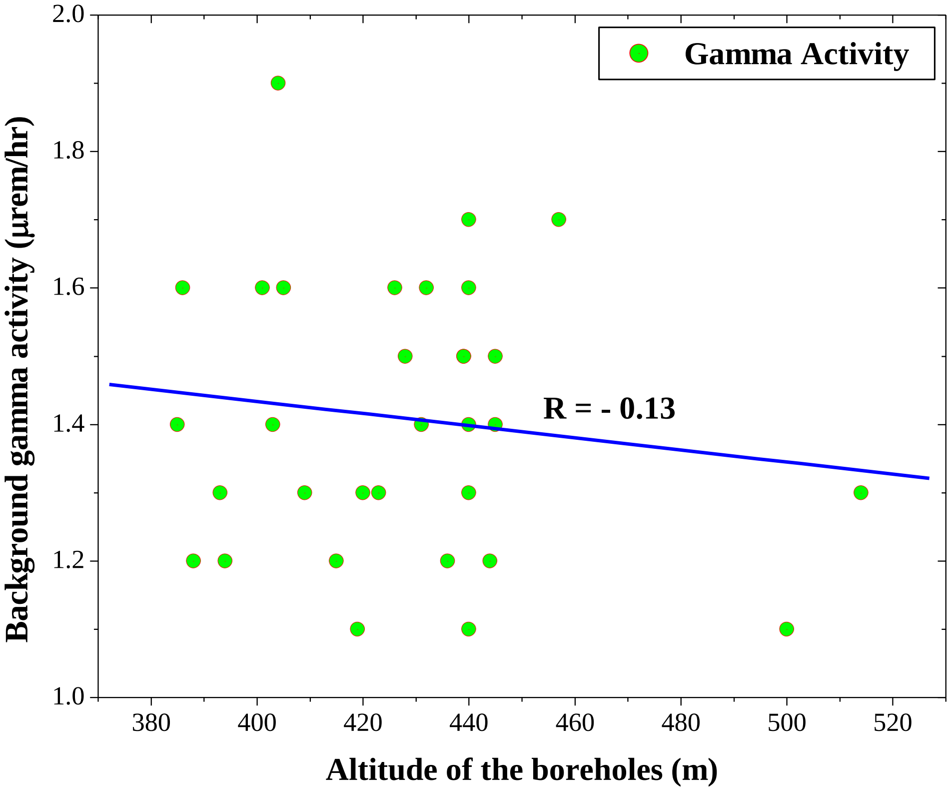

Fig. 2a

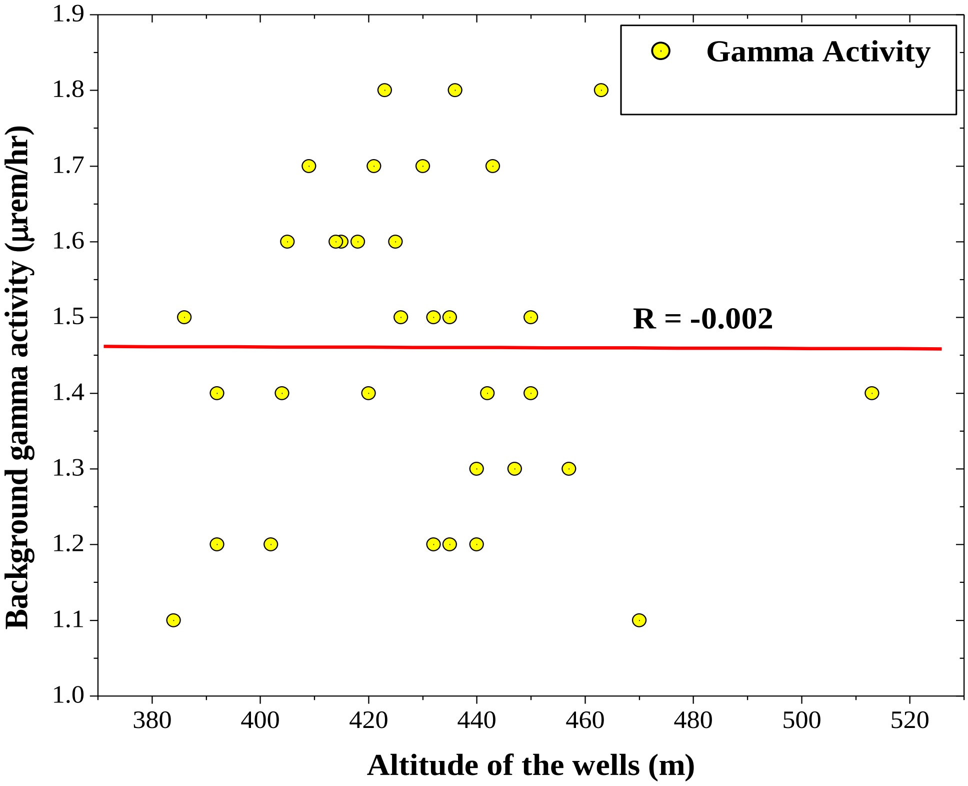

Fig. 2b
Fig. 2 Variation gamma exposure level with the altitude of the **a)** boreholes and **b)** wells

Fig. 2a shows an inverse relation between gamma exposure level and altitude of the measurement sites (boreholes). To have a quantitative measurement of the relationship between them Pearson Correlation Coefficient has been calculated (**Steele, 2004**). Measured value of the correlation coefficient factor (R) of - 0.13 reveals a very low negative correlation between background gamma exposure levels with the altitude of the boreholes.

In **Fig. 2b,** no significant relationship has been observed between background gamma exposure levels with the corresponding altitude. To know the strength of the relationship, Pearson correlation coefficient has been estimated. It gives a correlation coefficient factor (R) of - 0.002 which suggests almost no correlation between gamma exposure level and altitude of the measurement sites (wells).

Therefore, from the above findings, it is clear that with higher altitudes background gamma exposure level around the boreholes slightly decreases while that around the wells is almost same because of the low variation of altitudes of the wells.

In view of the exposure in the gamma radiation, annual effective dose has been calculated. Estimated dose level around the boreholes are presented in **Table 1**.

From **Table 1**, it can be observed that for boreholes, the estimated AED has been varied between 13.50 – 23.31 µSv/yr with an average of 17.29 µSv/yr and for wells, the same ranges between 13.50 to 22.08 µSv/yr with an average of 17.92 µSv/yr. All the obtained dose values are lower than the United Nations Scientific Committee on the Effects of Atomic Radiation

(UNSCEAR) proposed world average reference gamma radiation dose value of 70 μSv/yr (**UNSCEAR 1998, 2000**).

To have a comparative view between the obtained dose values of the present work with the other researcher's findings, the measured values of worldwide outdoor gamma dose levels have been presented in **Table 2**.

Table 2 Worldwide measurements of outdoor gamma dose level

Location	Annual effective dose (μSv/yr)			Reference
	Min	Max	Average	
Cáceres, Spain	11.04	282.07	69.41	Baeza *et al*., 1994
Chhatrapur beach, India	460.00	6120.00	2000.00	Mohanty *et al*., 2004
Kestanbol, Turkey	-	-	268.58	Merdanoğlu and Altınsoy 2006
Lorestan province, Iran	79.72	203.58	138.58	Gholami *et al*. 2011
Chao Phraya river basin, Thailand	100.10	110.80	104.60	Santawamaitre *et al*. 2011
Abuja, Nigeria	130.00	260.00	182.73	Oyeyinka *et al*. 2012
Rishikesh, Haridwar, Narora, and Allahabad river basin, India	99.74	176.60	123.66	Sharma *et al*. 2014
Gwagwalada, Nigeria	128.77	139.81	133.68	James *et al*. 2014
Nasarawa, Nigeria	61.40	216.70	121.06	Kerinja *et al*. 2020
Ebonyi, Nigeria	171.70	233.02	196.22	Echeweozo and Ugbede 2020
Dutse, Nigeria	13.50	23.21	17.61	Present Study

From **Table 2** we can see that the outdoor gamma dose values of the present study area is well below than the other results. The wide differences between these gamma dose values with the present study may be due to the soil type, rocks structure, local geological settings and altitude differences (UNSCEAR 2000; Chiozzi *et al*. 2002; Dragović *et al*. 2006). Also the higher degree of industrialization compared to the current study area could also account for it.

Though the annual effective dose values are well below the recommended world average level, for lifetime radiation exposure, excess lifetime cancer risk has been estimated both for boreholes and for wells. For boreholes the calculated ELCR values are varied between 0.048 – 0.082 × 10^{-3} with an average value of 0.061 × 10^{-3} and for wells the calculated ELCR values are varied between 0.048 – 0.078 × 10^{-3} with an average value of 0.064 × 10^{-3}. All the ELCR values are well below the UNSCEAR recommended world average ELCR value of 0.29 × 10^{-3} (UNSCEAR 2008; Taskin *et al*. 2009; ICRP 2010). Based on the radiological parameters estimated in this study, it can be concluded that individuals who visit the sample location daily to collect water or reside in the vicinity of the study area face a low risk of developing cancer.

CONCLUSION

The measured gamma exposure levels in the boreholes are varied from 1.1 - 1.9 μrem/hr with an average of 1.5 μrem/hr and around the wells it varies between 1.1 – 1.8 μrem/hr with an average of 1.5 μrem/hr. No significant correlation has been found between gamma exposure levels and the altitudes of the sites.

Estimated annual effective dose values are well below the UNSCEAR proposed reference limit of 70 μSv/yr and the Excess Lifetime Cancer Risk values for all the sampling points are far below the WHO proposed world average reference level .

Therefore, ndividuals who reside in the sampling areas and those who visit for collecting water for drinking and other household purposes are almost safe from outdoor gamma radiation exposure. It is highly recommended that additional research works should be carried out using larger sample sizes and varied sampling techniques in order to gain a more comprehensive understanding of the levels of exposure to background gamma radiation and the potential health hazards it poses to the population in this region.

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