In-Situ Measurement of Background Radiation Level in Zaria Local Government Area, Kaduna State

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Abstract: An assessment of the ambient radiation level was conducted in Zaria Local Government Area (L.G.A). The measurement was performed using a portable radiation dosimeter based on a Geiger-Mueller tube. A total of 130 locations were examined throughout the local government area to gauge the ambient radiation in the environment. The recorded radiation values ranged from 322 counts per second (cps) to 378 cps. Across the surveyed regions, the radiation levels were generally similar and could be attributed to both natural and human-made sources. These measured values remain below the recommended threshold established by the International Commission on Radiation Protection (ICRP) for the general population, indicating no immediate occupational risk. It is advisable to conduct further investigation by analyzing soil and water samples from the area.

Keywords: Background-Radiation, Geiger-Mueller, Rural environment, Zaria Local Government.

INTRODUCTION

Exposure to ionizing radiation stems from two primary origins: sources that occur naturally and those that are created by human activities. Naturally occurring radioactivity found within the Earth's crust can be divided into two distinct categories: original and altered natural sources. Original sources of radiation arise from cosmogenic or primordial (terrestrial) origins and have been present on Earth since its earliest times. Altered natural sources mainly result from actions like mining, the utilization of fossil fuels, the manufacturing of fertilizers, or the incorporation of natural materials into construction. The latter is referred to as "technologically enhanced natural radiation" (TENR). Among these sources, natural radiation contributes the most to the cumulative global radiation exposure rate. In regions with typical background radiation, the primary contributor to higher radiation doses from natural sources is the inhalation of radon gas and its decay products (UNSCEAR, 2000). The naturally occurring radioactive materials (NORM) present in the environment are classified into two groups. The first group comprises materials like uranium, thorium series, and potassium-40 that originate from the Earth's crust. The second group consists of materials like C-14, Na-22, Be-7, and H-3 that are formed when atmospheric gases interact with cosmic rays. These materials exhibit radioactivity, a process in which radiation is emitted to attain nuclear stability, contributing to natural radiation levels.

When human exposure to radiation from these substances is increased due to human activities like mining, fertilizer production, oil and gas extraction, coal combustion, etc., the radioactive materials are termed as technologically enhanced NORM (TERNORM). The radiation emitted during the process of radioactivity can potentially lead to biological effects such as cancer (WNA, 2019). Ongoing surveillance of the mentioned sources of radiation is crucial, and it's imperative to adhere to the guidelines recommended by regulatory authorities to guarantee the safety of public health (Abdullahi, 2014). Establishing a natural baseline for background radiation holds significant importance, as this can serve as a reference point for identifying any elevation in radiation levels. This is particularly critical for swiftly detecting potential radiological emergencies, ensuring the well-being and safety of the public (USNRC, 2017). Determining the foundational values of these radiations would create a radiation map of the surroundings. The objective of this study is to assess the background radiation levels within the Zaria local government area.

Radioactivity

Radioactivity refers to the automatic release of particles (such as alpha, beta, and neutron) or radiation (such as gamma and k capture), or a combination of both, resulting from the decay of specific nuclides due to a modification in their internal structure. A nucleus is considered stable when the nuclear force triumphs over the repulsive force, and there is a sufficient amount of binding energy. When the ratio of protons to neutrons reaches a point where equilibrium cannot be maintained, the nucleus becomes unstable, as the binding energy is insufficient to preserve nucleon balance. Achieving stability is a natural inclination for any physical system (Momoh, 2013).

The unstable nucleus endeavors to achieve stability through an internal, spontaneous transformation, leading to a modification of the N/Z ratio toward a more stable configuration.

Radionuclides like uranium-234, thorium-232, and potassium-40 raise significant concerns due to their extended half-lives (USNRC, 2017). Upon ingestion, these radionuclides are eliminated through bodily processes, including excretion by the kidneys (Nuccetelli *et al.*, 2012). The kidneys may become strained in the process, potentially resulting in kidney damage or failure (Pellegrini *et al.*, 2017). Additionally, certain radionuclides, such as radium-226 (226Ra), radium-228 (228Ra), and radon-222 (222Rn), known as bone seekers, share chemical similarities with body minerals. These radionuclides may accumulate in the bone marrow, posing a risk of cancer over time (Gyuk, 2017).

226Ra transforms into the noble gas 222Rn with a half-life of 3.82 days, allowing the gas to escape into the atmosphere. Inhalation of radon gas contributes to internal radiation exposure, potentially leading to an annual effective dose of 1.2 mSv. Radon typically accounts for approximately half of the effective dose from natural background radiation. When radon decays in the air, it produces non-gaseous radioactive daughters. Inhaling these daughters can result in their retention in the respiratory system, becoming a significant source of internal radiation exposure and causing deleterious effects (Turner, 2007; Isinkaye and Anbi, 2013).

Short-lived radon isotopes, such as 219Rn and 220Rn, with half-lives of 4 and 56 seconds, respectively, also contribute to the health hazard. The risk associated with radon exposure is closely tied to the air concentration of potential alpha-particle energy from these short-lived daughter sources of naturally occurring radioactive materials (NORMs).

Sources of NORMs

Naturally Occurring Radioactive Materials (NORMs) have diverse origins, and all living organisms experience continuous exposure to ionizing radiation from these sources. The degree of exposure varies based on geographical location and altitude, with a reported factor of about 3, according to the UNSCEAR 2000 report (UNSCEAR, 2000). The primary contributors to this exposure include:

i. Cosmic rays originating from outer space and the sun's surface; ii. Terrestrial radionuclides present in the Earth's crust; iii. Found in building materials and air; iv. Present in water and various food sources; v. Existing within the human body.

Conducting an assessment of the doses resulting from these natural sources is crucial, as they have been identified as the most substantial contributors to the collective dose experienced by the global population. Cosmic radiation is noted for its intensity at higher altitudes, while localized areas may exhibit elevated concentrations of uranium and thorium in soils. The exposure to radiation from the concentration of potassium-40 (40K) in foods has been determined to be relatively constant and uniform for individuals worldwide (UNSCEAR, 2000).

Table 1 shows the worldwide average annual effective doses for the various sources;

Table 1: Average radiation exposure from natural sources (UNSCEAR, 2000)

Source	Worldwide average annual effective dose, mSv	Typical range
External		
Cosmic rays	0.4	0.3 -1.0
Terrestrial rays	0.5	0.6 – 0.6
Internal		
Inhalation (Radon)	1.2	0.2 - 10
Ingestion	0.3	0.2 – 0.8
TOTAL	2.4	1 – 10

Source: Faanu, 2011

Absorbed Gamma Dose rate (Dy)

The overall absorbed dose rate in the air resulting from the average activity concentrations of 238U, 232Th, and 40K, measured at a 1-meter height above the ground using the radionuclide concentrations obtained from environmental materials (Ferdous *et al.*, 2016).

$$D_y = 0.462A_u + 0.604A_{Th} + 0.042A_k - - - (1)$$

Annual effective dose rate (AEDR) [annual effective dose equivalent (AEAE)]

The permissible value of 0.48mSy^{-1}

$$AEDE_{in}\left(\frac{mSv}{yr}\right) = D_y(nGy/h) \times 10^{-6} \times 8760h/y \times 0.20 \times 0.7Sv/G_y) - - - (2)$$

$$D_y = Total\ absorbed\ dose\ rate\ in\ air$$

AEDE with occupancy of 20% and 80% for indoor human effective dose equivalent (Karim *et al.*, 2016).

Excess lifetime cancer risk (ELCR)

The probability of developing cancer over a lifetime at a given radiation exposure level.

$$ELCER = AEDE \times DL \times RF$$

$$AEDE = Annual\ effective\ dose\ equivalent,$$

$$DL = duration\ of\ life\ estimated\ to\ be\ 70years\ and\ RF = risk\ factor\ (Sv^{-1}).$$

For stochastic effects, ICRP uses RF as 0.05 for the general public. The permissible ELCT value$is\ 0.29 \times 10^{-3}$.

METHODS

Zaria local government is located between latitude 09^0 02N and 11^0 32'N and longitude 06^0 15'E and 08^0 38'E, it has an average elevation above sea level of 626m (2053 ft) km^2 (Abaje *et al.*, 2015) it has Thirteen (13) political words.

An in-situ radiation measurement was performed using a portal Geiger Mueller (GM) survey meter placed on erect support at a height of 1m above the ground level uniform distribution of the naturally occurring radio-nuclides (Ononugbo, *et al* 2016). The point of measurement was randomly selected and covered all 13 wards of Zaria local government. Ten measurements were made at each ward and then the average of the reading was completed to obtain the average measurement for each ward. A handheld GPS meter reading was obtained at each point of the ward measurement and the average was taken. The data were randomly taken from 130 points in the LGA. And the result is presented in the Table below.

RESULTS AND DISCUSSION

Background radiation measurements were effectively gathered for various locations within the Zaria Local Government Area (L.G.A.) using a GM counter. The mean and standard deviation of counts per second (cps) for different locations were computed using Microsoft Excel and are presented in the tabular format provided below.

Table 2: Radiation Measurements for Different Locations Showing Maximum Counts per Second

S/N	Location (Ward)	Long. (°N)	Lat. (°E)	K CPS	U CPS	Th CPS	Total CPS	Dose Rate(nG/h)
1	Wucicciri	10.95969	007.77801	2.8	0.8	0.4	322.0	070.7
2	Dambo	11.07843	007.78344	3.1	1.1	0.9	338.4	118.6
3	D/Abba	11.03069	007.66489	4.1	1.2	0.7	341.4	130.1
4	Gyellesu	11.04490	007.69154	4.6	1.5	1.0	351.4	159.5
5	T/wada	11.02617	007.69907	5.0	2.4	1.8	378.9	227.9
6	Kaura	11.03663	007.71501	4.6	1.4	1.2	353.1	161.6
8	Ang/Liman	11.0377	007.72363	3.9	1.7	1.1	358.2	166.8
9	Kwarbai B	11.08246	007.70142	2.5	1.2	0.6	332.9	105.1
10	T/Tukur	11.08648	007.70306	3.6	1.3	0.9	345.0	137.5
11	Limanci	11.08672	007.70290	4.6	1.4	1.0	354.4	158.0
12	Kufena	11.07989	007.68253	3.9	1.7	1.3	354.0	167.4

Source: Information gathered for the IBR project in January 2023 indicates variations in the total counts per second (cps) among different locations. Additionally, there are discrepancies in the peak counts per second, which pertain to the highest recorded values of count/second.

The cumulative counts of background radiation for different locations are graphically represented using a bar chart. This chart displays the names of places along the x-axis and the corresponding count/second values along the y-axis, as illustrated below.

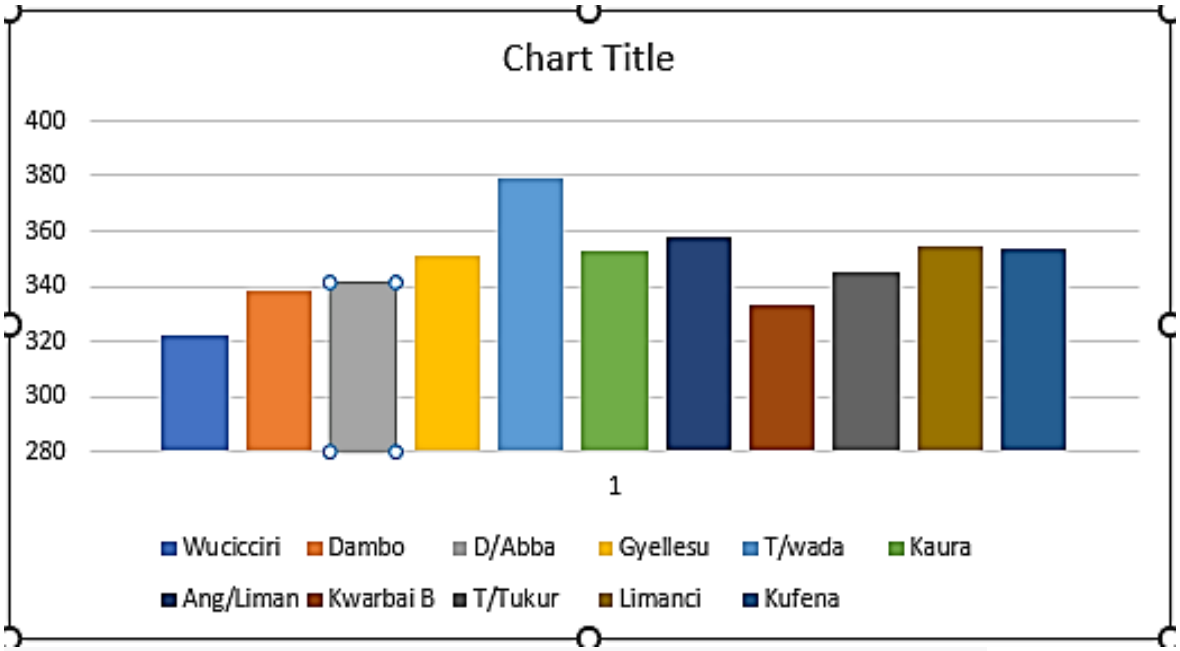

Figure 1: Fluctuation in Maximum Count/Second Values Across Various Locations

There are minimal substantial changes observed in the entry of radioactive particles into the GM tube when it is shifted across diverse areas within four locations. As a result, the counts have been grouped into specific categories. However, in the case of seven locations, there are noteworthy variations in the count rates when moving the device across various spots. Consequently, the data has been divided into two segments based on the total values. That is the place with the highest peak places like T/wada Limanci, Ang. Liman, Kufena, Kaura, and Gyallesu, the high peak of this area may be a result of a crowd of people in the area because most of the places above are the urban area of the study area where there are too many activities that may enhance the background radiation like hospitals, industries, as well as vehicles, in particular, T/wada is highest may be because of the A.B.U. Teaching Hospital has been in the area While in the other parts places like Wucciciri, Dambo, and D/abba, are places at the lowest peak, maybe as a result they are located in the rural part of the study area where there are low activities that enhance background radiation.

Numerous investigations have previously been conducted to assess the degree of radiation exposure in workplaces such as hospitals and industries. However, this particular study does not center on occupational exposures; instead, its emphasis is on the general populace's exposure to background radiation levels. The observations extended beyond the designated study area to ascertain whether the ionizing radiations employed in hospitals and industries pose a greater potential risk to the public.

CONCLUSION

The conclusions derived from the investigation conducted to assess the count per second of background radiation within Zaria L.G.A indiated that the lowest radiation value was recorded at Wucicciri, measuring 322 counts per second (cps). A slightly elevated background radiation level was detected in Kufena, reaching 354 cps. The increase might be attributed to unauthorized mining activities in the area due to the abundance of rocks, on the other hand, the highest cps values were observed at T/wada, reaching 378 cps. Additionally, this could be due to the heightened exposure to cosmic rays linked to its high-altitude location. No significant radiation hazard from background radiation was observed among individuals in both high cps and low cps areas.

This study clearly verifies that radioactivity is not a continuous occurrence, as radiation is observed in discrete counts. The count numbers vary over fixed time intervals during multiple observations.

RECOMMENDATIONS

This research has studied levels of radioactivity in Zaria LGA and makes the following recommendations, which can be potential avenues for future research, as derived from the analysis of this study, including:

1. Exploring the background radiation levels of Zaria L.G.A by examining additional nearby locations such as Sabon Gari.
2. It is imperative to seek a conversion methodology that can elucidate the health implications associated with background radiation counts.

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