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Measurement of Background Ionizing Radiation in Kogi State, Nigeria

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ABSTRACT: Radiation is said to be energy that is in motion and manifests itself everywhere we look in the form of waves or particles which can either useful or dangerous. Since radiation has always existed in the environment since the earth's origin, daily exposure to varied levels of ionizing radiation is inevitable for humans. Therefore, environmental radioactivity measurements are crucial for measuring the background radiation level caused by naturally occurring radioactive sources with terrestrial and cosmic origins because of these effects on living beings. The aim of this paper is to measure and record the background radiation of various locations evenly distributed across the twenty-one (21) local government areas of Kogi State and use the measured value to produce a reliable and easily accessible background radiation contour map for Kogi State using ArcGIS 10.3. Using a portable RDS-31 Multi-survey meter, the dose rate of background ionizing radiation (BIR) was measured in µSv/hr and the result shows that Ankpa LGA has the lowest mean readings of 0.096 µSv/hr and 0.1682 mSv/yr for the annual equivalent dose rates. Yagba East had the highest mean reading of 0.2300µSv/hr and highest annual equivalent dose rates of 0.4030mSv/yr. The result shows that eventhough the AEDE are greater than the 0.07mSv/yr global average value, however they are all below the ICRP's recommended permitted limits of 1.00mSv/yr. This demonstrates that there are no immediate radiological health effects on the general people as a result of BIR exposure in the examined locations. It is recommended that the various human activities that raise BIR levels in the regions should be reduced and that activity concentrations of natural radionuclides and BIR levels in the state be periodically assessed.

KEYWORDS: Ionizing, GIS, Kogi state, Radiation, Radioactivity, Nigeria.

INTRODUCTION

Radiation is said to be energy that is in motion and manifests itself everywhere we look in the form of waves or particles. X-rays, gamma rays, microwaves, radio waves, visible light, infrared and ultraviolet rays are all types of radiation (Rajan, 2017). It has been discovered that radiation can be both damaging and useful. Cancer, cataracts, gene mutation, the deterioration of bones and blood cells, and the possibility of death are only a few of the negative impacts (Jwanbot, 2011). Since radiation has always existed in the environment since the earth's origin, daily exposure to varied levels of ionizing radiation is inevitable for humans (Ugbede and Echeweozo, 2017). Given that it is an unavoidable component of the environment, this radiation, known as background ionizing radiation (BIR), has gained a lot of attention from the general public worldwide. Primordial or terrestrial radiation, cosmic radiation, and radioactivity in the human body are the three main sources of radiation (Ike, 2003). The primordial radionuclides $_{40}K$, $_{238}U$, and $_{232}Th$, which came from the planet's crust and are still present everywhere in the environment—in rocks, soil, water, sediments, foods, and even the human body. Cosmogenic radiation enter the earth from space as cosmic radiations which interacts with atmospheric conditions and are deposited by means of dry and wet deposition (UNSCEAR, 2008). Additionally, there is radioactivity in the air, mostly as a result of the presence of the easily accumulating gases Radon ($_{222}Rn$) and Thoron ($_{220}Rn$), which are byproducts of the $_{238}U$ and $_{232}Th$ decay series, respectively (Farai and Vincent, 2006; Okeyode and Oluseye, 2010).

Man can be exposed to a variety of man-made sources, as well as natural sources that have been boosted by human activity (anthropogenic), in addition to the unavoidable natural background radiation sources. Examples of such are burning coal, oil, and other fossil fuels. Therefore, the average radiation exposure of 2.4 mSv/yr is caused by cosmic radiation, terrestrial (NORMs), radon, anthropogenic activities such a variety of medical and industrial uses, consumer items, fallout from nuclear testing and accidents, etc. Environmental radioactivity measurements are crucial for measuring the background radiation level caused by naturally occurring radioactive sources with terrestrial and cosmic origins (Shashikumaret al., 2008) because of these effects on living beings (UNSCEAR, 1993). Health physics places a great deal of importance and interest in studies of natural environmental radiation and radioactivity because doing so can be helpful for estimating public dose exposure rates and maintaining reference data records to track potential changes in the environment's radioactivity over time (Ningappa et al. 2008).

Although the location's geology, geographical features, and human activity play a major role in the distribution and availability of these radionuclides (Bouzarjomehriet al. 2005), natural background radiation makes a sizable contribution to the annual effective dose that the general public receives (Ugbede and Echeweozo, 2017). Therefore, the general public's most crucial and pressing concern is understanding the sources of natural background radiation (Chandrashekara et al. 2012, Szegvary et al. 2007). The World Nuclear Association (2014) summarized the normal average public exposure to natural radiation, which is shown in Table 1. Despite the broad worldwide summary provided in Table 1, there are significant variances based on the altitude and geology of specific areas. For instance, records have shown that Ramsar in Iran has a natural radiation exposure level of 10 mSv/yr, while Kerala and Madras State in India have exposure levels up to 30 mSv/yr. While the beach in Brazil with the greatest natural radiation level, 800 mSv/yr, is unoccupied (Henriksen and Maillie 2003).

Table 1: Typical Natural Radiation Exposure to people in Public

Source of exposure	**Annual Effective Dose (*mSv*)**		
		Average	**Typical Range**
Cosmic radiation	Direct photon and ionization Component	0.28	
	Nuclear element	0.10	0.01-0.3
	Radionuclides from Cosmogenic	0.01	
	Cosmogenic and the full spectrum	0.39	
External terrestrial radiation	Outdoors	0.07	
	Indoors	0.41	0.05-0.4
	Total radiation emitted by land surfaces	0.48	
Inhalation	Uranium and thorium series	0.006	
	Radon(Rn-222)	1.15	0.001-1.0
	Thoron(Rn-220)	0.10	
	Total exposure from inhalation	1.26	
Ingestion	K-40	0.17	
	Uranium and thorium series	0.12	0.1-0.2
	Total exposure from ingestion	0.29	
Total		2.42	1.2-1.9

(**Source:** World Nuclear Association, 2014).

The ALARA principle, a radiation protection practice, states that radiation exposure should be maintained as low as practically practicable. Therefore, regulatory agencies and radiation protection scientists have as one of their main objectives the assessment of exposure to ionizing radiation (Osimobiet al. 2015). In order to maintain the ALARA principle due to the fatal effects of ionizing radiation, any region with a perceived high radiation level is subjected to an accurate assessment of the exposure level, quantification, and categorization of the radiation dosage. Understanding how much radiation we are exposed to in the natural world is the first step in preventing overexposure.

The human body system frequently adjusts to this background radiation level without experiencing any negative health impacts, however any exposure above this point may result in certain health issues. The overexposure is primarily caused by human activities and operations, such as farming, quarrying, mining, and burning fossil fuels (Salehet al. 2007). This is due to the operations increasing the exposure rate by bringing significant amounts of buried material containing naturally existing radionuclides to the surface of the environment. Therefore, in order to create a trustworthy and accessible background radiation contour map for Kogi State, the aim of this study is to measure and record the background radiation at various places uniformly distributed across the twenty-one (21) local government areas of Kogi State, Nigeria.

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THE STUDY AREA

North-central Nigeria is home to Kogi State. Due to the fact that the confluence of the Rivers Niger and Benue lies at Lokoja, the state's capital and the original administrative center of contemporary Nigeria, it is often referred to as the Confluence State. The State is located between latitudes 7^0 30' N and 7^0 50' N and longitudes 6^0 42' E and 6^0 70' E. It has a 29,833 sq km land area. The State is the only one in Nigeria that shared border with ten (10) other States (Fig.1) in the country and having twenty-one (21) Local Government Areas (LGAs). Federal Capital Territory and Niger State form its northern border, followed by Kwara State in the north-west, Nasarawa State in the north-east, Ondo and Ekiti States in the west, and Benue State in the east. Additionally, it borders the states of Enugu, Edo, and Anambra to the south, west, and east, respectively. Moreover, Kogi State is divided into the Kogi east, Kogi central, and Kogi west senate districts. The entire Kogi State was covered by this survey.

Fig. 1: Map of Nigeria showing Kogi State (modified from Obaje, 2009)

Fig. 2: Map of Kogi State, Nigeria showing the LGAs

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MATERIALS AND METHODS

The following is a list of the resources utilized in the research that pertain to the different phases of the project;

a) Map of the Kogi state.

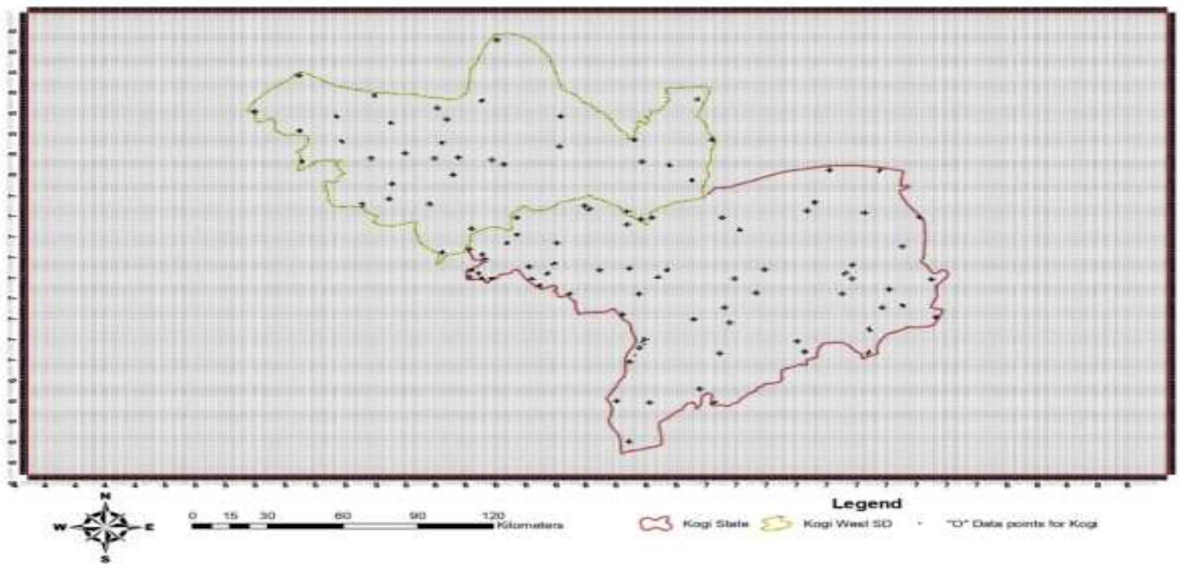
b) RDS-31 Multi-survey meter, which is especially made to work as a survey meter for low-level radiation. It is the best option for radiation monitoring in the environment.

c) Global Positioning System (GPS). in order to pinpoint the exact latitude and longitude coordinates of the sites.

d) Stop watching

Kogi east senatorial district, which includes the following local government areas and their acronyms, and the other three senatorial districts were all the locations of the study, which was conducted in August 2021. They include: Ankpa (AN), Bassa (BA), Dekina (DE), Ibaji (IB), Idah (ID), Igalamela/Odolu (IG), Ofu (OF), Olamoboro (OL) and Omala (OM). The central senatorial district which comprises the following local government areas and abbreviations: Adavi (AD), Ajaokuta (AJ), Ogorimagogo (OG), Okehi (OK) and Okene (OKN). And the western senatorial district which consists of the following local government areas and abbreviations: Ijumu (IJ), Kabba/Bunu (KB), Koton Karfi (KK), Lokoja (LK), Moppa Muro (MM), Yagba East (YE) and Yagba West (YW). To cover all the LGAs, two teams of two people each were employed. The two teams received training on how to operate the survey meter before beginning data collection.

Using a portable RDS-31 Multi-survey meter (with a serial number of 3000249 produced by Mirion Technologies (RADOS) OY, Finland), the dose rate of background ionizing radiation (BIR) was measured in μSv/hr. The detector is capable of detecting x-rays, γ- rays, and β-particles. The background radiations were measured during data collection using an RDS-31 Multi-survey meter that was oriented vertically upwards. Five data points from each LGAs were deliberately selected for this study. Five readings were made from each data point at a distance of exactly one meter from the center of the data point (making a total of twenty five reading points per local government). To uniformly cover the study area, the points were carefully selected (see Map 1) with help of GIS program. The GIS program was used to create the coordinates for the primary data points as well as the subsequent five reading regions for each data point. To allow sampling points to keep their original environmental properties, an in-situ approach of measurement at 1.0 m above the ground level was employed.



Map 1: Map of Kogi state, divided into grids of 1km by 1km (represented by the dots), showing the generated sample points at intervals of approximately 1km apart.

In order to establish an average dose rate per data point, five measurements of the dosage rate in μSv/hr were taken from each data point and averaged using SPSS version 24 (this value is what is presented in this report). The RDS-31 Multi-survey meter's display screen allowed users to view the measured data. Based on UNSCEAR (2008) guidelines, the average dose rates in μSv/hr were then translated to equivalent dose (ED) rates in mSv/yr. 0.2 outdoor occupancy factors were advised based on the norms. This occupancy factor is the percentage of a person's overall exposure time to a radiation field. There were eight thousand seven hundred and sixty hours (8760hr/yr) used. Hence equation (i) below was used in the conversion.

AEDR (mSv/yr) = (μSv/hr) × 8760 (hr/yr) × 0.2 ÷ 1000.......... (i)

Where AEDR is the outdoor annual effective dose rates

Overall, ArcGIS 10.3 was used to produce various maps using the readings obtained from the field. Due to their high dosage rate measurements and quick shift in results, Kogi West senatorial district and Yagba West LGA in particular have received more attention.

RESULTS AND DISCUSSIONS

To determine the mean value of the sensor readings across all local government areas, the data were collected and recorded and entered into SPSS; the results are shown in Table 2. Also shown in Table 2 is the computed AEDR using equation (i).

Table 2: Mean BIR Readings for the Twenty One LGAs

LGAs code	LGAs Name	Mean (μSv/hr)	AEDR (mSv/yr)
AD	Adavi	0.1700	0.2978
AJ	Ajaokuta	0.1408	0.2467
AN	Ankpa	0.0960	0.1682
BA	Bassa	0.1580	0.2768
DE	Dekina	0.1380	0.2418
IB	Ibaji	0.1380	0.2418
ID	Idah	0.2200	0.3854
IG	Igalamela/Odolu	0.1110	0.1945
IJ	Ijumu	0.1284	0.2250
KB	Kabba/Bunu	0.1368	0.2397
KK	Koton Karfi	0.1380	0.2418
LK	Lokoja	0.1550	0.2716
MM	Mopa Muro	0.1748	0.306
OF	Ofu	0.1480	0.2593
OG	Ogori Magongo	0.1776	0.3112
OK	Okehi	0.1700	0.2978
OKN	Okene	0.1424	0.2495
OL	Olamaboro	0.1710	0.2996
OM	Omala	0.1530	0.2681
YE	Yagba East	0.2300	0.4030
YW	Yagba West	0.2012	0.3525
Average		0.157	0.275

Source: Authors' field survey, 2021.

From Table 2, the twenty LGAs' mean equivalent dose rates per hour were determined to be 0.157 μSv/hr and their equivalent dose rates annually were calculated to be 0.275 mSv/yr. Ankpa local government area has the lowest mean readings of 0.096 μSv/hr and 0.1682 mSv/yr for the annual equivalent dose rates. Yagba East had the highest mean reading of 0.2300μSv/hr and highest mean annual equivalent dose rates of 0.4030mSv/yr. Figure 1 also depicted the mean equivalent dose rate graphically.

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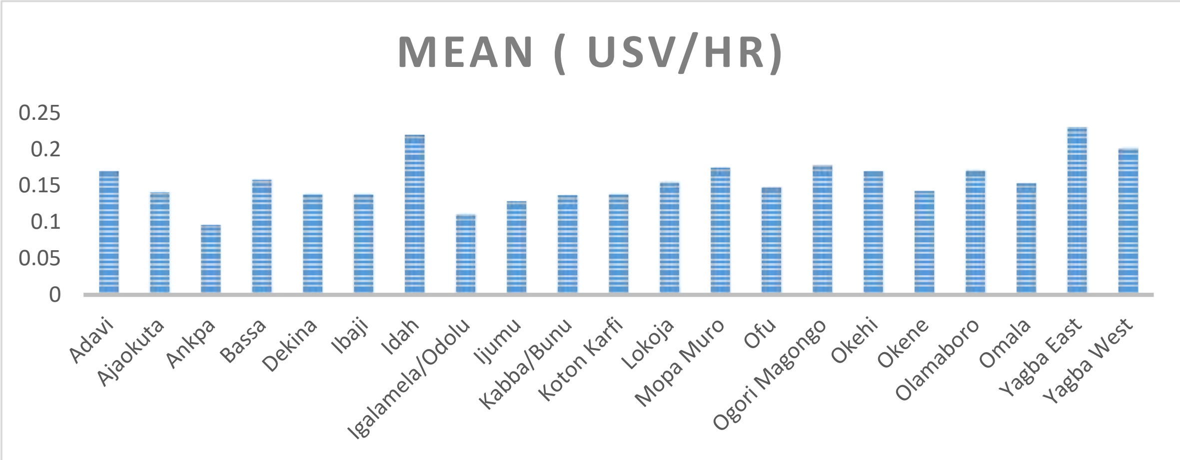
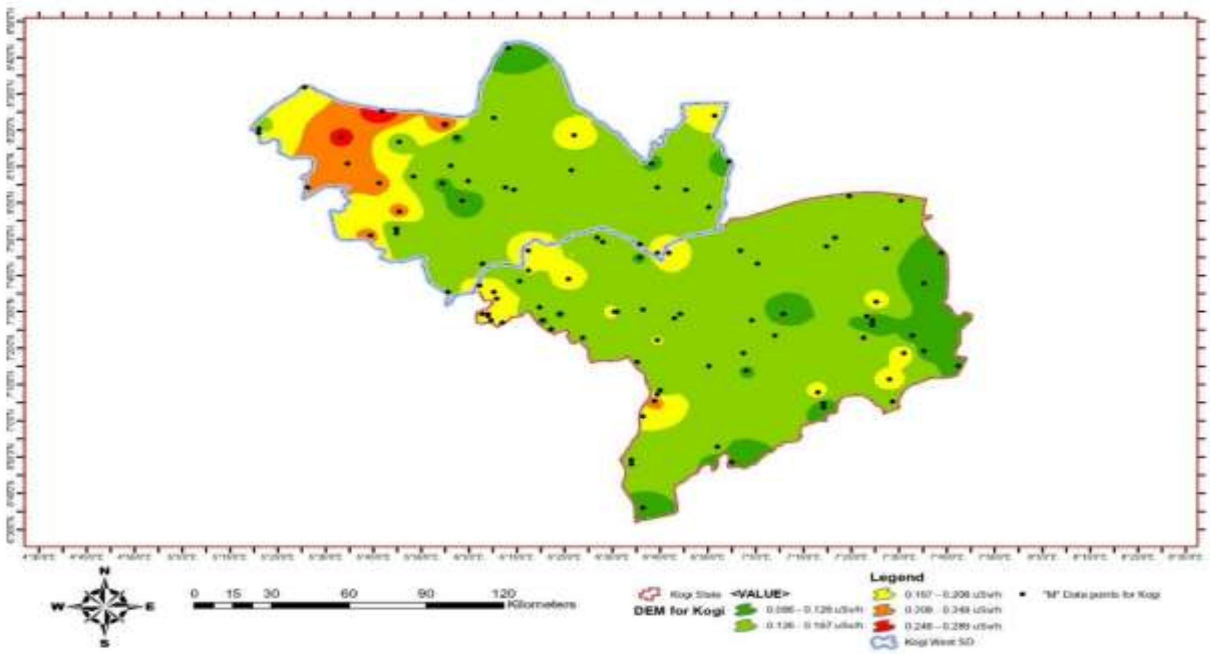


Figure 1. shows the average readings for all LGAs.

All of the AEDE are greater than the 0.07mSv/yr global average value (Agbalagba, 2017; Mugren, 2015), however they are all below the ICRP's recommended permitted limits of 1.00mSv/yr for the general public and 20.00mSv/yr for occupational workers within a year (ICRP, 1990). This demonstrates that there are no immediate radiological health effects on the general people as a result of BIR exposure in the examined locations (i.e., the LGAs), which are in good compliance with the allowed limit.

This paper also present some contour maps using ArcGIS of the study area and show relationships among the mean readings obtained and the world average Dose rate.



Map 2: Digital Elevation Model (DEM) image of Kogi state, interpolated from the average DP (as "Z" factor), with Kogi West Senatorial district inserted for focus. (See legend for DEM interpretation). "Z" values used here were measured in uSv/hr, then averaged.

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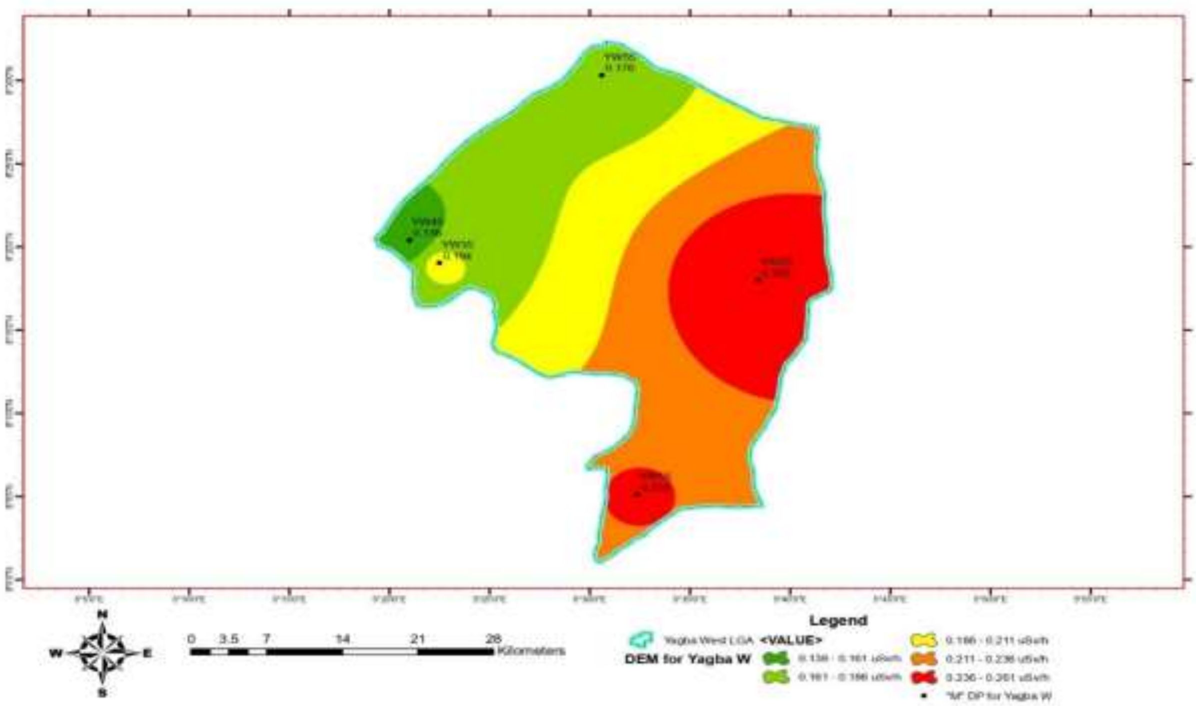
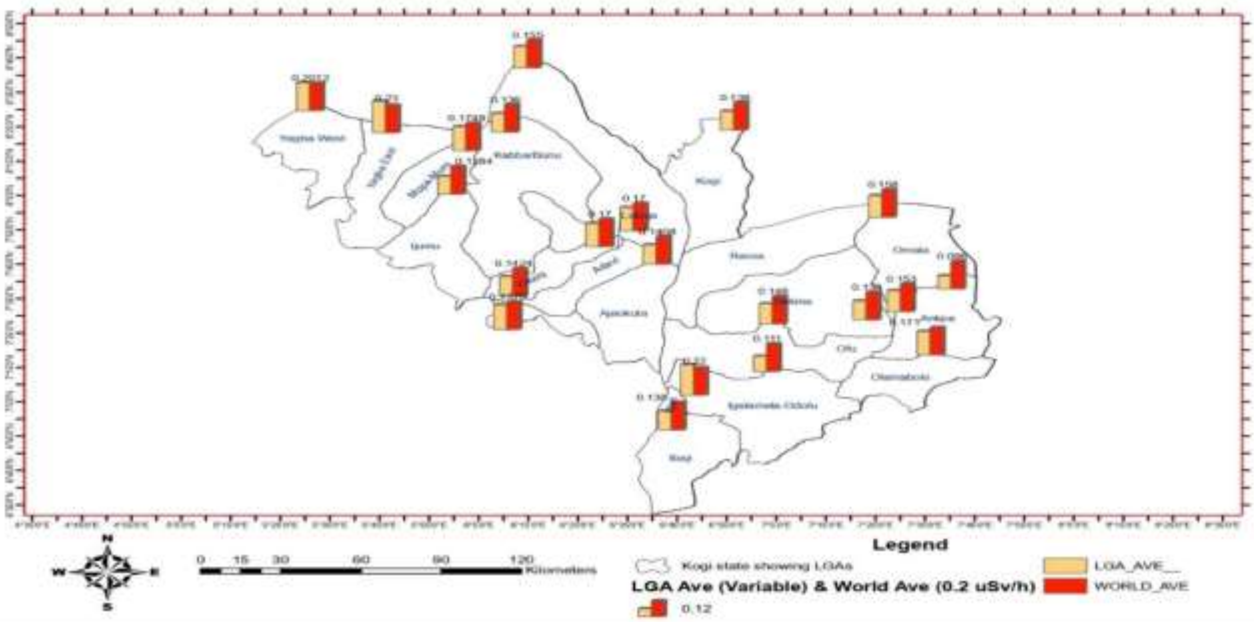


Map 3: Digital Elevation Model (DEM) image of Yagba West LGA of Kogi state, interpolated from the average DP (as "Z" factor) measured in uSv/hr), labeled with the unique local identification code (LIC) and the average dose rate for the original 5 Data points (DP). (See legend for DEM interpretation).



Map 4: Map of Kogi state showing the various LGAs and bar charts for LGA Average dose rate compared with the world average Dose rate. (See legend for chart interpretation). Units for the y axis are in measured in uSv/hr.

CONCLUSION

Natural Occurring Radioactive Materials (NORMs), which are extensively dispersed and exist in various geological formations such as water, rocks, and air, play an important part in our daily life. Buildings, food, grasses, and phantom radioactive elements are all present in the environment where we dwell as radionuclides. It's interesting to note that although they are radioactive in their natural condition and are only deemed to be at a background level, radionuclides stay safe for people and other living things up until they have an impact on the environment as a result of radionuclide-related human activities. Since human exposure to natural background radiation is a constant and inescapable facet of human existence, the qualitative and quantitative assessment of radiation exposure level and dosages within an environment is a crucial component of radiation protection. The goal of the current study is to objectively evaluate the background radiation levels in each LGA of Kogi State. According to the findings, Ankpa has the lowest BIR level and Yagba East has the highest BIR level.

The radiological evaluation reveals that there are no acute radiological health effects on the general public as a result of BIR exposure in the researched locations, but there is a lifetime risk of acquiring cancer in the studied surroundings, notably for those residing in Yagba east. To keep radiation levels as low as is reasonably possible, it is advised that various human activities that raise BIR levels in the region be reduced and that activity concentrations of natural radionuclides and BIR levels in the vicinity be periodically assessed. The study has been adequately described, and the conclusions will provide public health organizations, the government, and other researchers with baseline data that is crucial for planning and evaluating radiation protection programs as well as for future research.

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