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Assessment of Outdoor Background Radiation Level and its Radiological Hazards at Jimeta and Yola Towns of Adamawa State, Nigeria.

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Abstract

The radiation from different types of radionuclides has both advantages and disadvantages. However, detailed research reveals that the drawbacks of several radionuclides far outweigh their advantages, particularly in regions with high concentrations, posing alarming impacts on human health. The study focuses on assessing outdoor background radiation levels in Jimeta and Yola towns, Adamawa State, Nigeria. Using a well-calibrated portable halogen-quenched Geiger Muller (GM) detector at 20 locations, measurements were taken at an elevation of 1.0m above ground level, with GPS tracking for accurate location. The research evaluates radiological health hazards and radiation effective doses to different body organs based on outdoor background exposure rates. Comparison with recommended permissible limits reveals that mean values for outdoor background exposure levels (0.016 mRh^{-1}) and absorbed dose rates (147.46 $nGyh^{-1}$) exceed safety limits (0.013 mRh^{-1}, 84.0 $nGyh^{-1}$) set by UNSCEAR and ICRP. The total excessive lifetime cancer risk (ELCR) ranged from 0.33×10^{-3} to 2.61×10^{-3}, with a mean value of 0.78×10^{-3}, close to the world average lifetime cancer limit (1.45×10^{-3}). Despite the mean annual effective dose equivalent (AEDE) (0.2219$mSvy^{-1}$) being below the recommended limit of 1.00 $mSvy^{-1}$ for general public exposure, and effective doses to various body organs remaining below 1.0 $mSvy^{-1}$, the study indicates potential long-term health hazards such as cancer due to accumulated doses. Generally, the study shows that Jimeta and Yola Metroplis is relatively safe radiologically with little contamination which could be attributed to the geological formation and partly due to human activity such as market and car park for transport system in the area. However, the contamination will not pose any immediate radiological health effect on resident of the area but there is tendency for long –term health hazards in the future such as cancer due to doses accumulated. It is therefore recommended that regular radiation monitoring exercise should be conducted on the area from time to time in order to checkmate both the workers and the members of public from high radiation exposure.

Keywords: Radiation, radiological, background radiation, effective doses and cancer risk

INTRODUCTION

Throughout life, humans are exposed to various risks from environmental contaminants, with natural and anthropogenic sources contributing to these risks. One permanent and unavoidable risk is associated with natural (terrestrial and cosmic) radiation (Hanfi, 2019; UNSCEAR, 2008). Radiation has been found to be both beneficial and harmful, encountered

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in everyday activities with varying forms and intensities. Harmful effects include cancer, cataracts, gene mutations, destruction of bones and blood cells, and even the potential for causing death (Rilwan *et al*., 2021). Outdoor terrestrial natural radiation is primarily influenced by the presence of naturally occurring radionuclides in soils, with their distribution in sand, soil, and rock being crucial for radiation measurement and protection (Mubarak *et al*., 2017; Vasconcelos *et al.,* 2009).

The gamma radiation emitted from these radionuclides in external exposures depends on geological and geographical conditions, leading to variations between regions globally (Mubarak *et al*., 2017; Ugbede and Benson, 2018). In 1990, the International Commission on Radiation Protection (ICRP) established a worldwide annual equivalent dose rate limit of exposure to ionizing radiation at 1mSv/yr for human beings and wildlife (UNSCEAR, 2008). Simultaneously, the United Nations Scientific Committee on the Effects of Atomic Radiations (UNSCEAR) set an average effective dose rate limit of 2.4mSv/yr for most indoor facilities, such as research laboratories, conference halls, lecture venues, offices, etc. (UNSCEAR, 2020). While previous studies have identified areas with high background radiation in Yangjiang, China; Kerele, India; and Ramsar, Iran (Althoyaib and El-Taher, 2019). Maximum outdoor measurements were recorded in Malaysia and maximum indoor measurements in Hong Kong and Iran (Alshahri *et* ., 2019). In Nigeria, outdoor background ionizing radiation has received more attention than indoor background ionizing radiation, despite studies indicating dangerous background ionizing radiation within buildings. Investigating indoor background ionizing radiation is crucial because lifestyle changes mean people spend more time indoors than outdoors. Surveys from the World Health Organization (WHO) and the International Commission on Radiological Protection (ICRP) indicate that residents of temperate climates spend only about 20% of their time outdoors and 80% indoors, in their homes, offices, schools, and other buildings (Felix *et al.,* 2015). Several studies in Nigeria have determined natural radiation levels in different areas. For example, a study in Keffi and Akwanga in Nasarawa State reported mean annual effective dose equivalents due to outdoor radiation exposure ranging from 0.25 mSv/y to 0.31mSv/y, below the recommended dose limit of 1 mSv/y (Termizi *et al.,* 2014). Nationwide studies indicate a mean annual effective dose equivalent of 0.27mSv/y (Farai and Jibri, 2000). A survey of gamma terrestrial radiation in Nigerian coal mines indicated mean outdoor readings of 10.4 nGy/h and 11.7 nGy/h for the Okaba and Okpara mines, respectively (Mokobia and Balogun, 2004). This study assesses the outdoor background radiation level and radiological hazards in Jimeta and Yola metropolis, Adamawa State, Nigeria.

Materials and Methods

Materials

The outdoor background radiations of Jimeta and Yola metropolis was determined using Inspector Alert Nuclear Radiation Meter, GPS, Biro and exercise book were used to record all data from the study area**.**

Study Area

Jimeta is located in the region of Adamawa State and has a population of 73,080 inhabitants according to the 1999 census results. It is the second largest town in Adamawa State. Adamawa's capital Yola is approximately 8.3km/5.1 mi away from Jimeta. The distance from Jimeta to Nigeria's capital Abuja is approximately 546km/339mi. Adamawa state is divided into 21 local government areas. (Census data Government records)

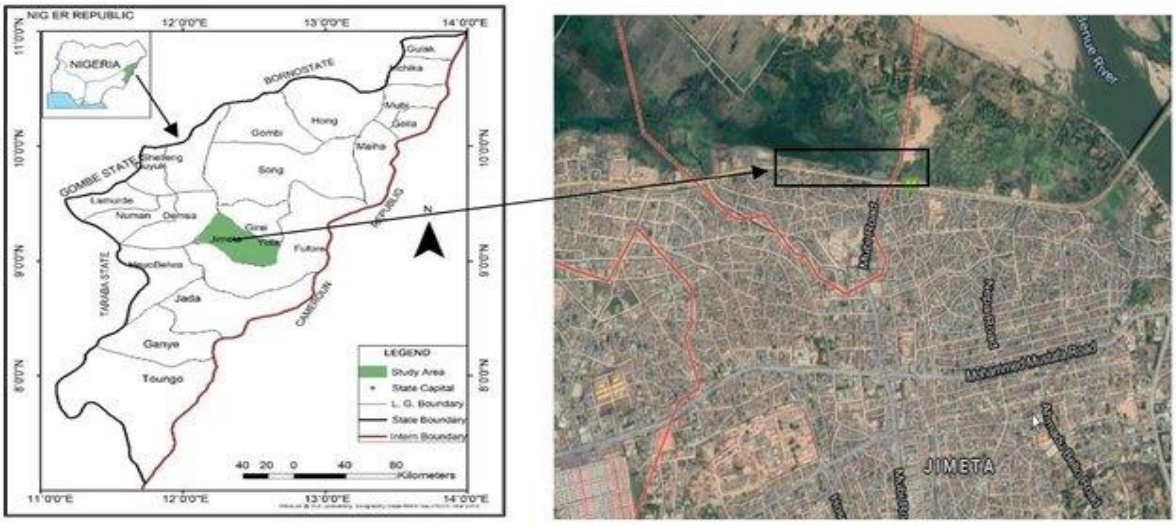

Figure. 1: Map of Study Area

Sampling and Measurement

Measurement of terrestrial outdoor exposure levels was done using a factory calibrated Inspector Alert Nuclear radiation meter (SN:35440, by SE international, Inc. USA). The meter's sensitivity 3500 CPM/ ($mR.h^{-1}$) referenced to Cs-137 and its maximum alpha and beta efficiencies are 18% and 33% respectively. It has a halogen-quenched Geiger-Muller detector tube of effective diameter of 45 mm and a mica window density of 1.5-2.0 $mg.cm^{-2}$ (Inspector alert operation manual). A total of twenty sample areas were selected arbitrarily in Jimeta and Yola metropoli Adamawa State. Background outdoor radiation readings were taking around some selected public places such as Abattoir Yola Road (AYR), Jemita Mordern Market (JMM), Kasuwan Guri Road, Jambutu Garage (JBG). The standard deviation of each data was obtained to account for the errors in the data. Readings were taking between the hours of 1200 and 1600 because the radiation meter has a maximum response to radiation within these hours as recommended by the National Council on Radiation Protection and Measurements (NCRP, 1993). An in-situ approach of measurement with the standard practice of raising the detector tube 1.0 m above ground level with its window facing the point under investigation was adopted to enable sample points maintain their original environmental characteristics (Ugbede and Benson, 2018; Agbalagba *et al.,* 2016). The locations of each of the sample point was determined using a geographical positioning system (GPS). The exposure rate that were obtained and quantitatively used to assess the radiation health impact to the public in the study area and radiation effective doses to different organs of the body by performing a number of radiological health hazard indices calculations using well established mathematical relations.

$$Count\ rate\ per\ minute\ (COMP) = 10^{-3}\ \text{Roentgen} \times \text{F} \quad (1)$$

where F is the quality factor, which is equal to 1 for external environments.

Radiological Hazard Indices

Absorbed Dose Rate (ADR) in Air

The absorbed dose is used to assess the potential for any biochemical changes in specific tissues. It quantifies the radiation energy that might be absorbed by a potentially exposed individual. The measured outdoor background exposure levels were converted to radiation absorbed dose rate in air using Equation 3 according to (Agbalagba,2016; Rafique, *et al.,* 2014).

$$1\mu Rh^{-1} = 8.7\eta \text{Gy}h^{-1} = \frac{8.7\times10^{-3}}{(1/_{8760y})}\ nGyy^{-1} \quad (2)$$

This implies that:

$$1mRh^{-1} = 8.7\eta Gyh^{-1} \times 10^{3} = 8700nGyh^{-1} \quad (3)$$

Annual effective dose equivalent (AEDE)

The AEDE is used in radiation assessment and protection to quantify the whole body absorbed dose per year. It is used to assess the potential for long-term effects that might occur in the future. The annual effective dose equivalent (AEDE) per year received by workers and the population is obtained from equation 4 (UNSCEAR, 2008).

$$AEDE(mSv.y^{-1})_{outdoor} = D(nGy.h^{-1}) \times 8760h \times CF \times OF \times 10^{-6} \quad (4)$$

where D is the absorbed dose rate in $nGyh^{-1}$, 8760h is the total hours in a year, CF is the dose conversion factor from absorbed dose in air to the effective dose in Sv/Gy (CF = 0.7 Sv/Gy), OF

is the occupancy factor, the expected period the members of the population would spend within the study area. OF = 0.2 for outdoor as it is expected that human beings would spend 20 % of their time outdoors as recommended by (UNSCEAR, 2008).

Effective dose to different body organs (D_{organ})

The D_{organ} estimates the amount of radiation dose intake to various body organs and tissues. The D_{organ} of the body due to inhalation was calculated using Equation 5 as given by (Ugbede and Benson,2018).

$$D_{organ}\ (mSvy^{-1}) = AEDE \times F \quad (5)$$

where F is the conversion factor of organ dose from air dose. The F value for whole body lungs, ovaries, bone marrow, testes, kidney, and liver as given by (ICRP 1996) are 0.68, 0.64, 0.58, 0.69, 0.82, 0.62, and 0.46 respectively.

Excess lifetime cancer risk (ELCR)

The ELCR was evaluated using the AEDE values as shown in Equation 6 according to (Agbalagba, *et al.*, 2016; Rafique, *et al.*, 2014).

$$ELCR = AEDE\ (mSvy^{-1}) \times DL \times RF \quad (6)$$

where DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For low dose background radiation, which is considered to produce stochastic effects, ICRP 103 uses a fatal cancer risk factor value of 0.05 for public exposure (ICRP, 2007).

RESULTS AND DISCUSSION

RESULTS

Table 1 displayed the findings of the outdoor background exposure level measurements together with the radiological health hazards or human health risk factors from Jimeta and Yola town. The evaluation was conducted using the questions 1-6. The effective dosage data for a few bodily organs in the research area are shown in Table 2. The research area's health state was evaluated using the following radiological health risks indices: organ dose (D_{organ}), annual effective dose equivalent (AEDE), excess lifetime cancer risk (ELCR), and absorbed dose rate (ADR).

Table 1: Outdoor background exposure levels and related radiological health hazards indices in Jimeta and Yola Metropolis, Adamawa State

Sampling Locations Code	Latitude	Longitude	E(mRh^{-1})	ADR (nGyh^{-1})	AEDE (mSv.y^{-1})	ELCR $\times 10^{-3}$
AYR1	9^{0}13′ 38 ″N	12^{0} 27′ 18 ″E	0.013	113.1	0.139	0.4865
AYR2	9^{0}13′ 36 ″N	12^{0} 27′ 13 ″E	0.016	138.2	0.171	0.5985
AYR3	9^{0}13′ 35 ″N	12^{0} 27′ 11 ″E	0.020	174.0	0.213	0.7455
AYR4	9^{0}13′ 35 ″N	12^{0} 27′ 09 ″E	0.014	121.8	0.149	0.5215
AYR5	9^{0}13′ 34 ″N	12^{0} 27′ 08 ″E	0.016	139.2	0.171	0.5985
JMM1	9^{0}16′ 25 ″N	12^{0} 26′ 23 ″E	0.018	156.6	0.192	0.6720
JMM2	9^{0}15′ 38 ″N	12^{0} 27′ 28 ″E	0.012	104.4	0.128	0.4480
JMM3	9^{0}16′ 32 ″N	12^{0} 26′ 09 ″E	0.016	139.2	0.171	0.5985
JMM4	9^{0}16′ 12 ″N	12^{0} 26′ 11 ″E	0.017	147.9	0.181	0.6335
JMM5	9^{0}16′ 21 ″N	12^{0} 26′ 13 ″E	0.011	95.7	0.117	0.4015
KGR1	9^{0}14′ 39 ″N	12^{0} 28′ 34 ″E	0.014	121.8	0.149	0.5215
KGR2	9^{0}09′ 11 ″N	12^{0} 38′ 11 ″E	0.010	87.0	0.107	0.3745
KGR3	9^{0}58′ 48 ″N	12^{0} 33′ 32 ″E	0.011	95.7	0.117	0.4095
KGR4	9^{0}17′ 33 ″N	12^{0} 18′ 18 ″E	0.011	95.7	0.117	0.4095
KGR5	9^{0}14′ 22 ″N	12^{0} 27′ 05 ″E	0.016	139.2	0.171	0.5985
JBG1	9^{0}18′ 35 ″N	12^{0} 25′ 38 ″E	0.07	609.0	0.746	2.6110
JBG2	9^{0}18′ 34 ″N	12^{0} 27′ 07 ″E	0.016	139.2	0.171	0.5985
JBG3	9^{0}19′ 50 ″N	12^{0} 24′ 39 ″E	0.016	139.2	0.171	0.5985
JBG4	9^{0}17′ 50 ″N	12^{0} 26′ 43 ″E	0.013	113.1	0.139	0.4865
JBG5	9^{0}19′ 23 ″N	12^{0} 25′ 57 ″E	0.009	78.3	0.96	3.3600
	Mean		0.0167	147.46	0.221	0.783

Table 2: Dose to different organs of the body in Jimeta and Yola Metropolis, Adamawa State, Nigeria

	SAMPLING LOCATION CODE	Whole body	Liver	Kidney	Testes	Bone Marrow	Overies	Lungs
1.	AYR1	0.095	0.064	0.086	0.114	0.096	0.081	0.089
2.	AYR2	0.116	0.079	0.075	0.099	0.083	0.099	0.109
3.	AYR3	0.144	0.098	0.132	0.175	0.167	0.124	0.136
4.	AYR4	0.101	0.069	0.092	0.122	0.103	0.086	0.095
5.	AYR5	0.116	0.079	0.075	0.140	0.083	0.099	0.109
6.	JMM1	0.131	0.088	0.119	0.157	0.132	0.111	0.123
7.	JMM2	0.087	0.059	0.079	0.105	0.088	0.074	0.082
8.	JMM3	0.116	0.079	0.106	0.140	0.118	0.099	1.109
9.	JMM4	0.055	0.083	0.112	0.148	0.125	0.105	0.116
10	JMM5	0.079	0.054	0.073	0.096	0.081	0.068	0.075
11.	KGB1	0.101	0.069	0.092	0.122	0.103	0.068	0.075
12	KGB2	0.073	0.049	0.066	0.088	0.074	0.062	0.068
13.	KGB3	0.079	0.054	0.073	0.096	0.081	0.068	0.075
14.	KGB4	0.079	0.054	0.073	0.096	0.081	0.068	0.075
15.	KGB5	0.116	0.079	0.106	0.140	0.118	0.099	0.109
16.	JBG1	0.507	0.343	0.463	0.612	0.515	0.433	0.477
17.	JBG2	0.116	0.079	0.106	0.140	0.118	0.099	0.109
18.	JBG3	0.116	0.078	0.106	0.140	0.118	0.099	0.109
19.	JBG4	0.095	0.064	0.086	0.114	0.096	0.081	0.089
20.	JBG5	0653	0.442	0.595	0.787	0.476	0.557	0.614
	Mean	0.148	0.088	0.135	0.181	0.142	0.129	0.192

Note * Abatuwa Yola Road (AYR) * Jemita Mordern Market(JMM) * Kasuwan Gwari Road(KGR) * Jambutu Garage (JBG).

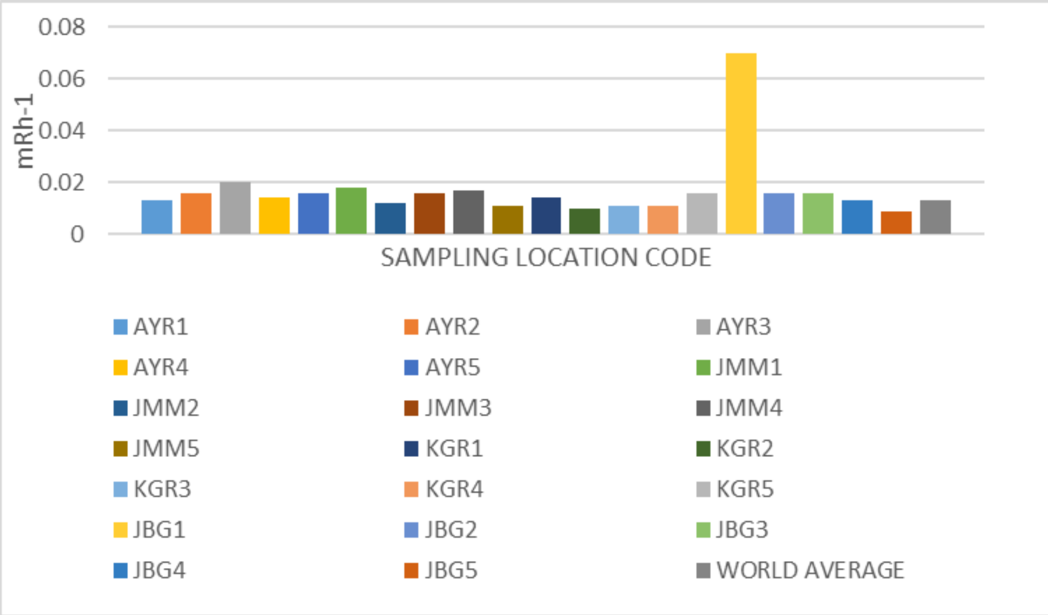

Figure.1: Outdoor Background Exposure Rate Levels

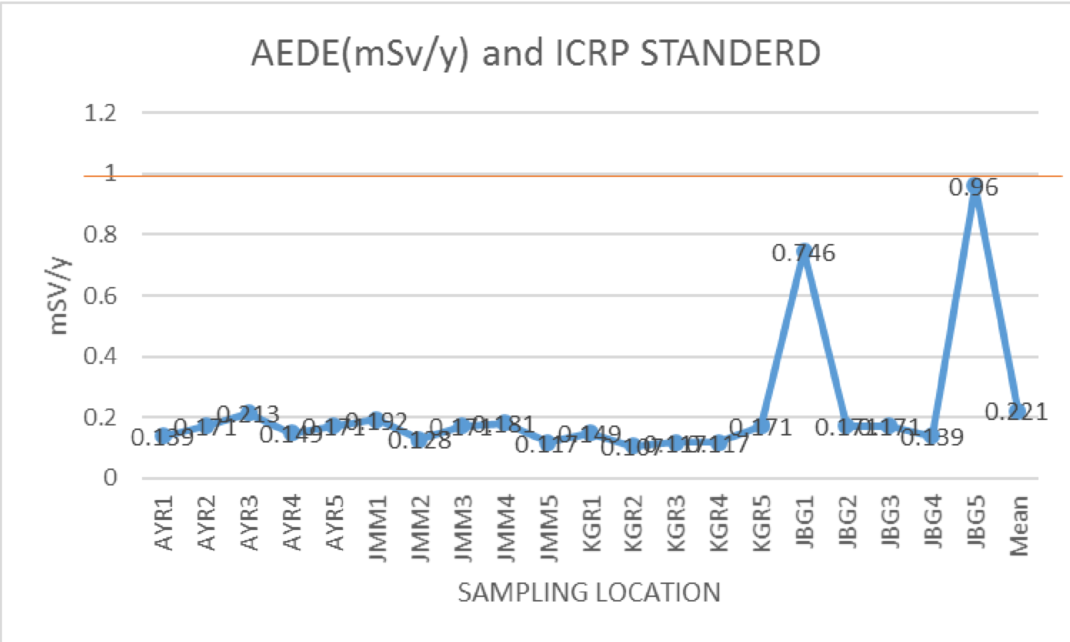

Figure.2: Comparison between the annual effective dose equivalent (AEDE) rate in Jimeta and Yola Metropolis and permissible safe limit

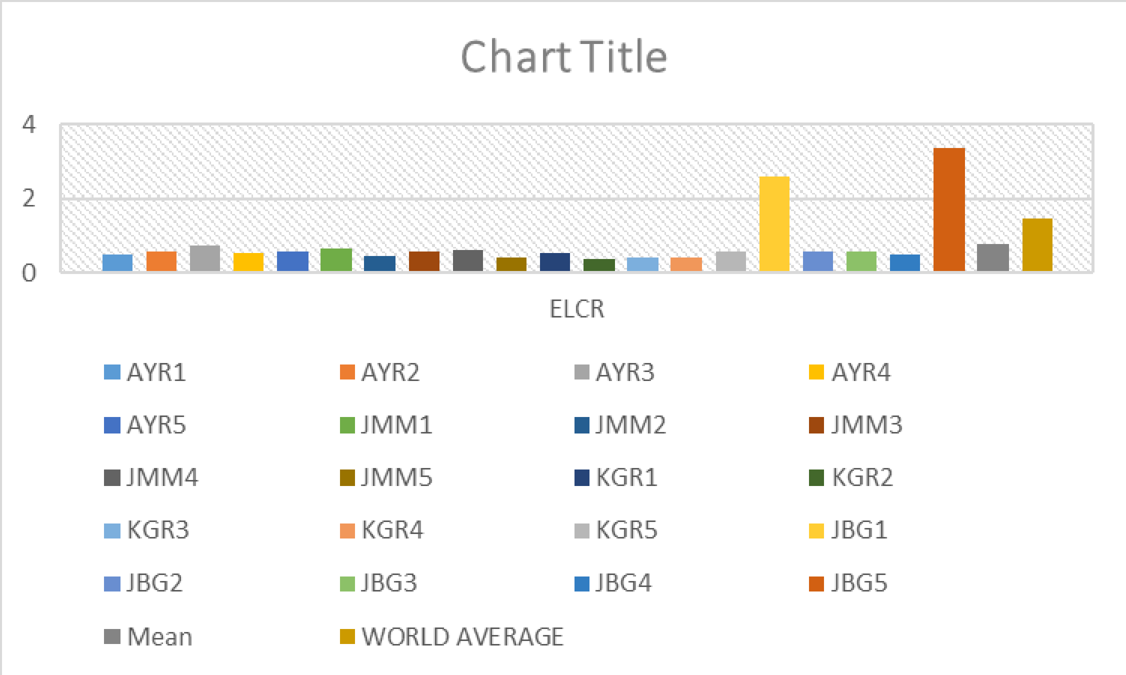

Figure.3: Comparison between the excess lifetime cancer risk (ELCR) $\times 10^{-3}$ in Jimeta Metropolis and world average

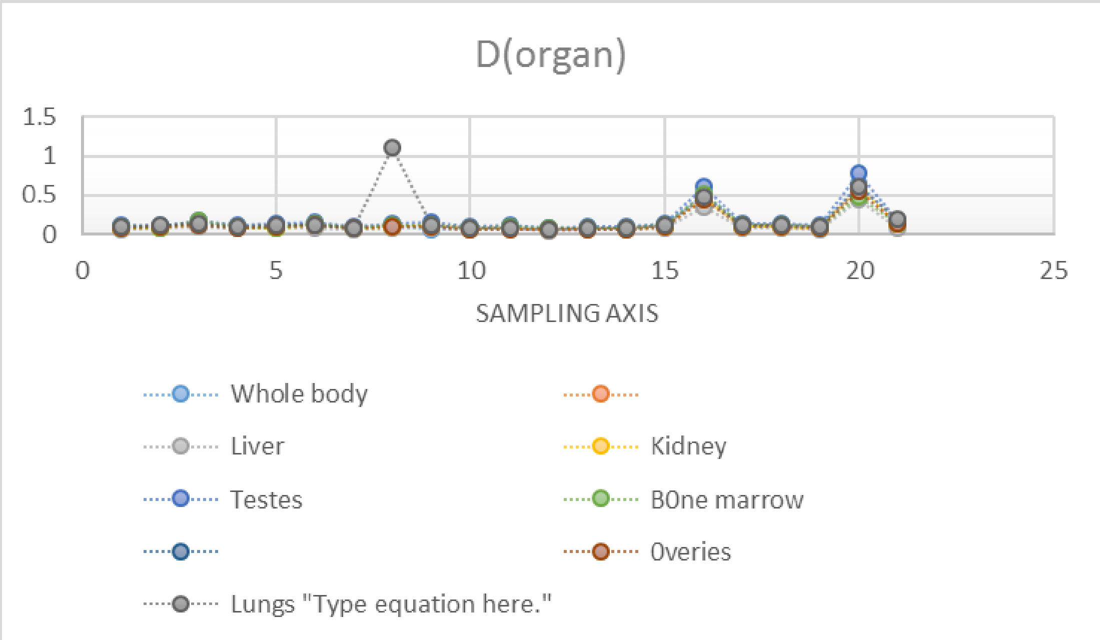

Figure.4: Comparison of the doses to different body organs

DISCUSSION

The various areas explored in this work are: Jemita Modern Market, Yola road Abatuwa, Jambutu park mechanic garage, Kasuwan Gwari bypass. The outdoor background exposure rate measured ranges from 0.009 to 0.070 mRh^{-1} with a mean value of 0.0167 mRh^{-1}. The mean outdoor background exposure rate for the environment studied exceeded the permissible recommended limit of 0.013 mRh^{-1} (Agbalagba *et al*., 2016; ICRP, 2007; Osimobi *et al*., 2015). The high exposure rate level in some areas is attributed to the geological formation, geophysical characterization, and man-made activity that contribute to the overall radiation level. Chemicals, petroleum products, and construction materials like granites, cement, asphalt, etc. (Agbalagba, *et al* 2016) have been identified to contain some radioactive elements available at the sampling points' locations. The high outdoor background levels indicate that the environment is radiologically unhealthy and contaminated for the general public. The mean exposure level reported here is higher than the 0.015±0.001mRh^{-1} and 0.018±0.004 mRh^{-1} value observed by (Ugbede and Benson 2018). in Emene Industrial Layout of Enugu State, Nigeria, and (Osimobi *et al* .2015) in solid mineral mining sites of Enugu State, Nigeria.

Absorbed Dose Rate (ADR) in air

For the absorbed dose rate, the calculated value range is between 78.3 nGyh^{-1} and 609.0 nGyh^{-1} with a mean (average) value of 147.46 nGyh^{-1}. The result is similar to that of (Idris *et al.*,2020). in Lafia, Nasarawa state. The mean absorbed dose rate appears to be higher than the recorded world-weighted average of 59.00 nGyh^{-1} (Osimobi *et al.*,2015; Ononugbo and Mgbemere, 2016). and the recommended safe limit of 84.0 nGyh^{-1} (Agbalagba, *et al.,* 2016), for outdoor exposure. These dose rates' results indicate contamination of the environment by radiation. Although the health effect on the residents of the locality may not be immediate, there is the potential for long-term health hazards in the future due to the accumulated doses. The mean dose rate from this investigation is higher than the 126.15 ± 5.10 nGyh^{-1} dose rates earlier reported by (Ugbede and Benson, 2018). In Emene Industrial Layout of Enugu State, Nigeria, but was below the 132.16±24.36 nGyh^{-1} for Ughelli metropolis in Delta State Nigeria by (Agbalagba, *et al* 2016).

Annual effective dose equivalent (AEDE)

The calculated values of AEDE range between 0.107 and 0.960 mSvy^{-1} with a mean value of 0.224 mSvy^{-1}. This is higher than the world average value of 0.07 mSvy^{-1} (Agbalagba *et al.* 2016; UNSCEAR 2008; ICRP, 2007) but within UNSCEAR and ICRP recommended permissible limits of 1.00 mSvy^{-1} for the general public (Agbalagba *et al.,* 2016; ICRP 2007). This indicates that the studied location is radiologically contaminated but still within the ICRP and UNSCEAR permissible limit. However, there is no immediate radiological health effect on members of the public. The AEDE from the present study is similar to those reported by (Ugbede and Benson, 2018). in Emene Industrial Layout of Enugu State, Nigeria, (Ononugbo and Mgbemere, 2016) in a fertilizer-producing area in Onne River State, and (Idris *et al.,* 2020) in Lafia metropolis, Nasarawa state, Nigeria.

Effective dose to different body organs ($\boldsymbol{D_{organ}}$)

Due to radiation exposure and inhalation in Jimeta and Yola Metropolis, the mean $\boldsymbol{D_{organ}}$ values assessed for the whole body, Liver, Kidney, Testes, Bone Marrow, Overies, and Lungs are,respectively, 0.148, 0.08, 0.135, 0.181, 0.142, 0.129, and 0.192 mSvy^{-1}. Figure 3 illustrates how Dorgan varies with respect to the various organs. The results show that the radiation levels do not have an immediate negative impact on the health of the study location's people since they are below the tolerated limits of 1.0 mSv annual (Agbalagba *et al.,* 2016). Based on the findings, it can be said that the liver and lungs are the organs most sensitive to radiation, respectively. The conclusions obtained by (Ugbede and Benson 2018; Agbalagba *et al.,* 2016; Idris *et al.,* 2020; and Darwish *et al.,* 2015), were similar. The range of AEDE's computed values is 0.107 to 0.960.

Excess lifetime cancer risk (ELCR)

Total excessive lifetime cancer Risk (ELCR) is found to be ranged between 0.33×10^{-3} to 2.61×10^{-3} , respectively, with a mean value of 0.78$\times 10^{-3}$, which is close to the world average (mean) value lifetime cancer limit 1.45$\times 10^{-3}$ (Qureshi et al., 20142). The risk is quite low, and the possibilities of cancer development by residents who wish to spend all their lifetime in the area are low. The ELCR values reported in this study are lower than those reported by Uburu Salt Lake environments of Ebonyi State, Nigeria, reported by (Avwiri, 2016), and (Agbalagba, *et al.,* 2016) in industrial areas of Warri, Nigeria, and also lower than those for Okposi Okwu Salt Lake and almost similar to that of (Idris *et al* 2021); in Lafia metropolis, Nasarawa state, Nigeria.

CONCLUSION

This study aimed to assess the radiological implications for the people of Jimeta and Yola Metropolis, Adamawa State, Nigeria, through an outdoor background radiation assessment. The radiation levels investigated are well within the recommended dose limits and align with the world average value reported by ICRP and UNSCEAR. Generally, Jimeta and Yola Metropolis are relatively safe radiologically with minimal contamination, attributed to geological formations and partly due to human activity. While the contamination doesn't pose immediate radiological health effects on residents, there is a potential for long-term health hazards, such as cancer, due to accumulated doses."

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