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Outdoor Background Radiation Level and Radiological Hazards Assessment in Lafia Metropolis, Nasarawa State, Nigeria

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Abstract: In this study, the assessment of the outdoor Background Radiation levels in Lafia Metropolis, Nasarawa State, Nigeria has been conducted. An in-situ measurement of outdoor background exposure rate count per minute for 20 locations was done using a well calibrated portable halogen-quenched Geiger Muller (GM) detector (Inspector alert Nuclear radiation monitor SN:3544) at an elevation of 1.0m above ground level with a geographical positioning system(GPS) for geographical location. Using an established radiological relations, the radiological health hazards and radiation effective doses to different body organs were evaluated using the measured outdoor background exposure rates. The values obtained were compared with recommended permissible limits to ascertain the radiological hazard status of the environment. The mean values of the outdoor background exposure levels (0.021 mRh-1), absorbed dose rates (184.875 nGyh-1) and excess lifetime cancer risk (0.794×10-3) are higher than their recommended safe limits of 0.013 mRh-1, 84.0 nGyh-1, 0.29×10-3respectively as recommended by UNSCEAR and ICRP. The mean annual effective dose equivalent (AEDE) (0.227 mSvy-1) is below recommended permissible limits of 1.00 mSvy-1 for general public exposure and also the effective doses to different body organs are all below the recommended limits of 1.0 mSvy-1. Generally, the study shows that Lafia Metroplis is relatively safe radiologically with little contamination which could be attributed to the geological formation and partly due to human activity 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.

Keywords: Radiation, radiological, assessment.

1. Introduction

The exposure of human beings to natural radiation, mainly due to natural radionuclides decay of ^{238}U (^{226}Ra) series, ^{232}T series and ^{40}K present in the earth's crust, in air, water, building materials, the human body and food. The major contributors of outdoor terrestrial natural radiation is the present of naturally occurring radionuclides in soils (Mubarak et al., 2017; Vasconcelos et al., 2013). Radionuclides are not distributed uniformly in the earth crust and the understanding of their distribution in sand, soil and rock are very important in radiation measurement and protection

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(Vasconcelos et al., 2009). The associated gamma radiation emitted from these radionuclides in external exposures depend on the geological and geographical conditions and vary between regions in the world (Mubarak et al., 2017; Ugbede, & Benson, 2018).

Humans are exposed to naturally radiation in their environment with or without their consent; and the exposure to natural background radiation is an unpreventable event on earth. Atomic radiation has no boundaries; and the injuries and clinical symptoms induced by exposure to ionizing radiation include; direct chromosomal transformation, indirect free-radical formation, radiation cataractogenesis, cancer induction, bone necrosis, etc (Termizi et al., 2014; Norman, 2008). The practice has been to ensure that human exposure to radiation is as low as reasonably achievable known as the ALARA principle.

There are high background radiation area (HBRA) regions in the world where the terrestrial outdoor radiation exceeds substantially from the normal range due to the enrichment of certain minerals that are radioactive (Vasconcelos et al., 2013; Termizi et al., 2014; Norman, 2008). Several countries like Iran, Germany, China, USA, Brazil, and India have reported the existence of high background radiation areas (Ugbede & Benson, 2018). The highest levels of natural radiation in the world have been reported in some areas in Ramsar with extraordinary radon level (Vasconcelos et al., 2009; Ugbede, & Benson, 2018; Ibikunle, Arogunjo & Ajayi, 2018). The data of radiation level obtained from HBRA in Ramsar recorded an effective dose of 260 mSv y^{-1}. This value is y far higher than the ICRP-recommended radiation dose limits for radiation workers, and over 200 times greater than normal background levels for members of the public (Ugbede, & Benson, 2018; Ibikunle, Arogunjo & Ajayi, 2018).

In Nigeria, several studies have been carried out in different areas to determine the natural radiation level in some location. For instance, it is reported by Termizi et al (2014) that the mean annual effective dose equivalent due to outdoor exposure to radiation in Keffi and Akwanga in Nasarawa State ranged from 0.25 mSv/y and 0.31mSv/y respectively which are below the recommended dose limit of 1 mSv/y. A study done nationwide to determine the terrestrial radiation in Nigeria indicates that the mean annual effective dose equivalent is 0.27mSv/y (Farai & Jibri, 2000). A survey of gamma terrestrial radiation in Nigerian coal mine indicated mean outdoor readings of 10.4 nGy/h and11.7 nGy/h for the Okaba and Okpara mines respectively (Mokobia & Balogun, 2004). This study assesse the outdoor background radiation level and radiological hazards in Lafia metropolis, Nasarawa State, Nigeria.

2. Materials And Methods

2.1 Study Area

Lafia is the capital city of Nasarawa State and has a population of 330,712 inhabitants according to the 2006 census results. It is the largest town in Nasarawa State.

The geographical entity known as Nasarawa State came into existence in October 1996. It has a central location in the Middle Belt region of Nigeria. The state lies between latitude 7^0 45' and 9^0 25' N of the equator and between longitude 7^0 and 9^0 37' E of the Greenwich meridian. It shares boundary with Kaduna State while Kogi and the Federal Capital Territory flanks it in the West. The state has a total land area of 27,137.8 square kilometer and a population of about 67 persons per square kilometer. Nasarawa state is divided into 13 local government areas.

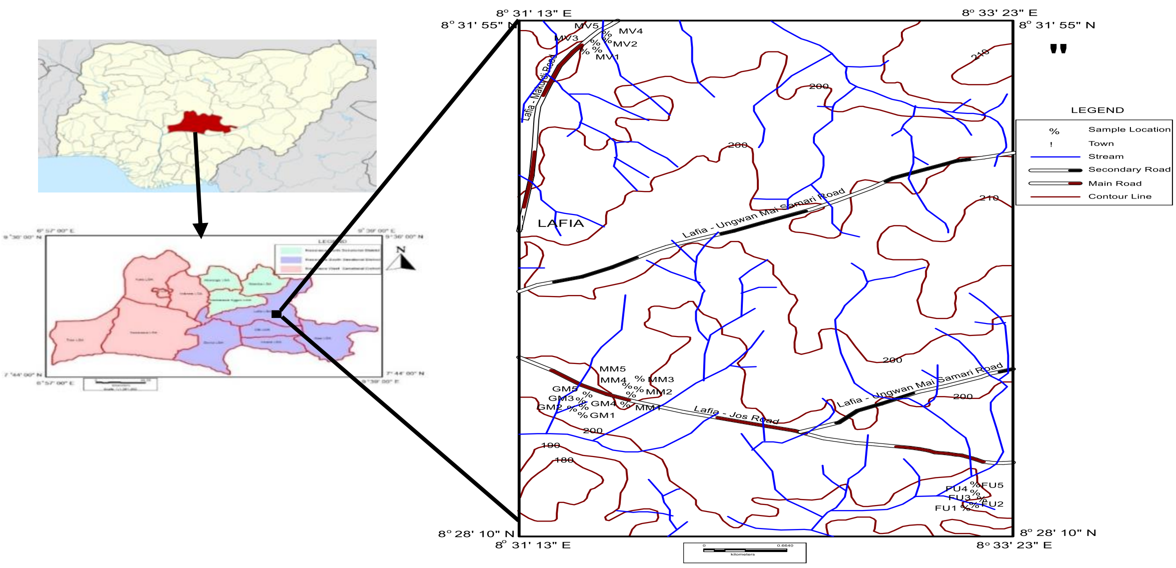

Fig. 1: Map of Study Area

2.2 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 Lafia, Nasarawa State. Background outdoor radiation readings were taken around some selected public places such as road side, schools, work places and so on. The standard deviation of each data was obtained to account for the errors in the data. Readings were taken 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 & Benson, 2018; Agbalagba, Avwiri & Ononugbo, 2016). The locations of each of the sample point were determined using a geographical positioning system (GPS). The exposure rate obtained were 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.

$$Count\ rate\ per\ minute\ (CMP) = 10^{-3}\ Roentgen\ x\ F \quad (1)$$

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

2.3 Radiological Hazard Indices

2.3.1 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, Avwiri & Ononugbo (2016) and Rafique et al (2014).

$$1\ \mu Rh^{-1} = 8.7\ \eta Gyh^{-1} = \frac{8.7x10^{-3}}{(1/8760y)}\ nGyy^{-1} \quad (2)$$

This implies that:

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

2.3.2 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; Gupta & Chauhan, 2011).

$$AEDE(mSv.y^{-1})_{outdoor} = D(nGy.h^{-1})x\ 8760h\ x\ CF\ x\ OFx10^{-3} \quad (4)$$

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).

2.3.3 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 & Benson (2018).

$$D_{organ}(mSvy^{-1}) = AEDE\ x\ F\ x\ 10^{-3} \quad (5)$$

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.

2.3.4 Excess lifetime cancer risk (ELCR)

The ELCR was evaluated using the AEDE values as shown in Equation 6 according toAgbalagba, Avwiri & Ononugbo (2016) and Rafique et al (2014).

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

where DL is average duration of life (70 years) and RF is the fatal cancer risk factor per sievert (Sv^{-1}). For lowdose 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).

3. Results And Discussion

The outdoor backgroud exposure level measurements results and the radiological health hazards parameters associated with them are preseted in table 1. Table 2 presents the effective dose results to some body organs in the study area. The radiological health hazards indices used in assessing the health status of the study area are absorbed dose rate (ADR), annual effective dose equivalent (AEDE), organ dose (D_{organ}) and the excess lifetime cancer risk (ELCR).

3.1 Outdoor Backgroung Exposure Rate Levels

The outdoor background exposure rate measured ranges from 0.011 to 0.090 mRh^{-1} with mean value of 0.021 mRh^{-1}. The mean outdoor background exposure rate for the environment studied exceeded the permissible recommended limit of 0.013 mRh^{-1} (Agbalagba, Avwiri & Ononugbo, 2016; ICRP, 2007; Osimobi et al., 2015). The high exposure rate level in some area is attributed to the geological formation, geophysical characterization and man made activity that cotributes to the overal radiation level. Chemicals, petroleum products, and construction materials like granites, cement, asphalt etc. Agbalagba, Avwiri & Ononugbo (2016) have been identified to contain some radioactive elements which are available in the sampling points locations. The high outdoor background levels indicates that the environment is radiologically unhealthy and contaminated for the general public. The mean exposure level reported here is higher than 0.015±0.001mRh^{-1} and 0.018±0.004 mRh^{-1} value observed byUgbede & Benson (2018) in Emene Industrial Layout of Enugu State, Nigeria and Osimobi et al (2015) in solid mineral mining sites of Enugu State, Nigeria.

3.2 Absorbed Dose Rate (ADR) in air

The range of calculated absorbed dose rate value is between 95.7 $nGyh^{-1}$ and 783.0 $nGyh^{-1}$ with observed mean value of 184.875 $nGyh^{-1}$. The mean absorbed dose rate appear to be higher than the recorded world weighted average of 59.00 $nGyh^{-1}$ (Agbalagba, Avwiri & Ononugbo, 2016; Monica et al., 2016) and recommended safe limit of 84.0 $nGyh^{-1}$ (Agbalagba, Avwiri & Ononugbo, 2016; Ononugbo & Mgbemere (2016) for outdoor exposure. These dose rates result idicates contamination of the environment by radiation. Although the health effect to the residents of the locality may not be immediate, but however there is the potential for long-term health hazards in the future due to the doses accumulated. The mean dose rate from this investigation is higher than 126.15 $\pm$5.10 $nGyh^{-1}$ dose rates earlier reported by Ugbede & Benson (2018) in Emene Industrial Layout of Enugu State, Nigeria but was below the 132.16±24.36 $nGyh^{-1}$ for Ughelli metropolis in DeltaState Nigeria by Agbalagba, Avwiri & Ononugbo (2016).

3.3 Annual effective dose equivalent (AEDE)

The calculated values of AEDE range between 0.171 and 0.960 $mSvy^{-1}$ with mean value of 0.227 $mSvy^{-1}$. This is higher than world average value of 0.07 $mSvy^{-1}$ (Agbalagba, Avwiri & Ononugbo, 2016; UNSCEAR, 2008; ICRP, 2007) but within UNSCEAR and ICRP recommended permissible limits of 1.00 $mSvy^{-1}$ for the general public (Agbalagba, Avwiri & Ononugbo, 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 are similar to those reported by Ugbede & Benson (2018) in Emene Industrial Layout of Enugu State, Nigeria and Ononugbo & Mgbemere (2016) in fertilizer producing area in Onne River State.

Table 1: Outdoor background exposure levels and related radiological health hazards indices in Lafia Metropolis, Nasarawa State

S/n	Sampling Location Code	Latitude	Longitude	E ($mR.h^{-1}$)	ADR ($nGy.h^{-1}$)	AEDE ($mSv.y^{-1}$)	ELCR
1	FU1	8^0 28’21.112’’ N	$8^0$33’11.728’’E	0.020	174.0	0.213	0.747

2	FU2	8^{0}28’21.113’’N	8^{0}33’11.729’’E	0.022	191.4	0.235	0.822
3	FU3	8^{0} 28’ 21.115’’N	8^{0}33’11.725’’E	0.090	783.0	0.960	3.360
4	FU4	8^{0}28’21.117’’N	8^{0}33’11.726’’E	0.018	156.6	0.192	0.672
5	FU5	8^{0}28’21.119’’N	8^{0}33’11.721’’E	0.029	252.3	0.309	1.083
6	GM1	8^{0}29’121’’N	8^{0}31’301’’E	0.014	121.8	0.149	0.523
7	GM2	8^{0}29’123’’N	8^{0}31’302’’E	0.017	147.9	0.181	0.635
8	GM3	8^{0}29’125’’N	8^{0}31’305’’E	0.016	139.2	0.171	0.597
9	GM4	8^{0}29’129’’N	8^{0}31’309’’E	0.017	147.9	0.181	0.635
10	GM5	8^{0}29’127’’N	8^{0}31’307’’E	0.033	287.1	0.352	1.232
11	MV1	8^{0}31’470’’N	8^{0}31’332’’E	0.011	95.7	0.117	0.411
12	MV2	8^{0}31’471’’N	8^{0}31’333’’E	0.013	113.1	0.139	0.485
13	MV3	8^{0}31’473’’N	8^{0}31’335’’E	0.012	104.4	0.128	0.448
14	MV4	8^{0}31’475’’N	8^{0}31’337’’E	0.014	121.8	0.149	0.523
15	MV5	8^{0}31’478’’N	8^{0}31’339’’E	0.015	130.5	0.160	0.560
16	MM1	8^{0}29’141’’N	8^{0}31’343’’E	0.018	156.6	0.192	0.672
17	MM2	8^{0}29’143’’N	8^{0}31’344’’E	0.021	182.7	0.224	0.784
18	MM3	8^{0}29’142’’N	8^{0}31’347’’E	0.012	104.4	0.128	0.448
19	MM4	8^{0}29’148’’N	8^{0}31’345’’E	0.013	113.1	0.139	0.485
20	MM5	8^{0}29’147’’N	8^{0}31’348’’E	0.02	174.0	0.213	0.747
	Mean			**0.021**	**184.875**	**0.227**	**0.794**

Table 2: Dose to different organs of the body in Lafia Metropolis, Nasarawa State, Nigeria

Sampling Location code	D_{organ}						
	Whole Body	**Liver**	**Kidney**	**Testes**	**Bone Marrow**	**Ovaries**	**Lungs**
FU1	0.145	0.098	0.132	0.174	0.147	0.124	0.137
FU2	0.159	0.108	0.146	0.192	0.162	0.136	0.150
FU3	0.652	0.442	0.595	0.787	0.663	0.557	0.615
FU4	0.131	0.088	0.119	0.157	0.133	0.111	0.123
FU5	0.210	0.142	0.192	0.254	0.214	0.179	0.198
GM1	0.102	0.069	0.093	0.122	0.103	0.087	0.096
GM2	0.123	0.083	0.112	0.149	0.125	0.105	0.116
GM3	0.116	0.078	0.106	0.139	0.118	0.099	0.109
GM4	0.123	0.083	0.112	0.149	0.125	0.105	0.116
GM5	0.239	0.161	0.218	0.289	0.243	0.204	0.225
MV1	0.079	0.053	0.073	0.096	0.081	0.068	0.075
MV2	0.094	0.064	0.086	0.114	0.096	0.080	0.089
MV3	0.087	0.059	0.079	0.105	0.088	0.074	0.082
MV4	0.102	0.069	0.093	0.122	0.103	0.087	0.096
MV5	0.109	0.074	0.099	0.131	0.110	0.093	0.102
MM1	0.131	0.088	0.119	0.157	0.133	0.111	0.123
MM2	0.152	0.103	0.139	0.184	0.155	0.129	0.143
MM3	0.087	0.059	0.079	0.105	0.088	0.074	0.082
MM4	0.094	0.064	0.086	0.114	0.096	0.080	0.089
MM5	0.145	0.098	0.132	0.175	0.147	0.124	0.137
Mean	**0.154**	**0.104**	**0.141**	**0.186**	**0.156**	**0.132**	**0.145**

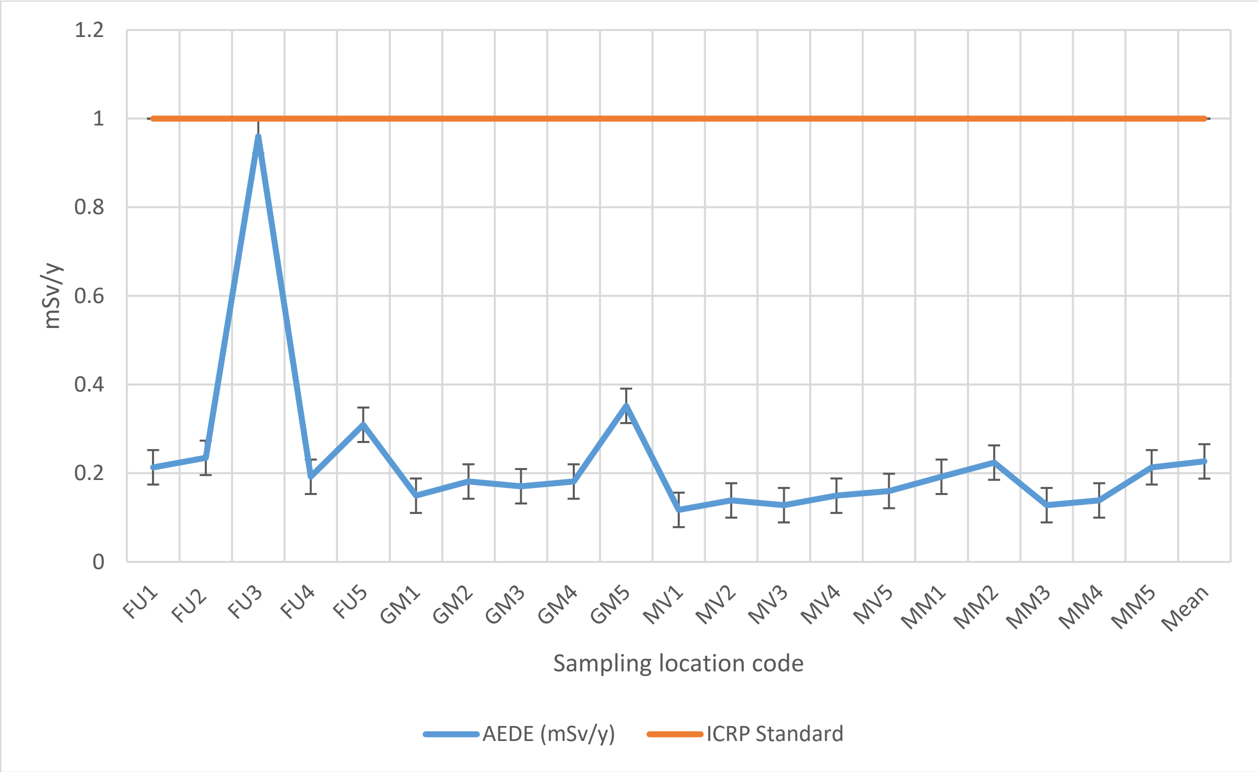

Fig. 1: Comparison between the annual effective dose equivalent (AEDE) rate in Lafia Metropolis and permissible safe limit

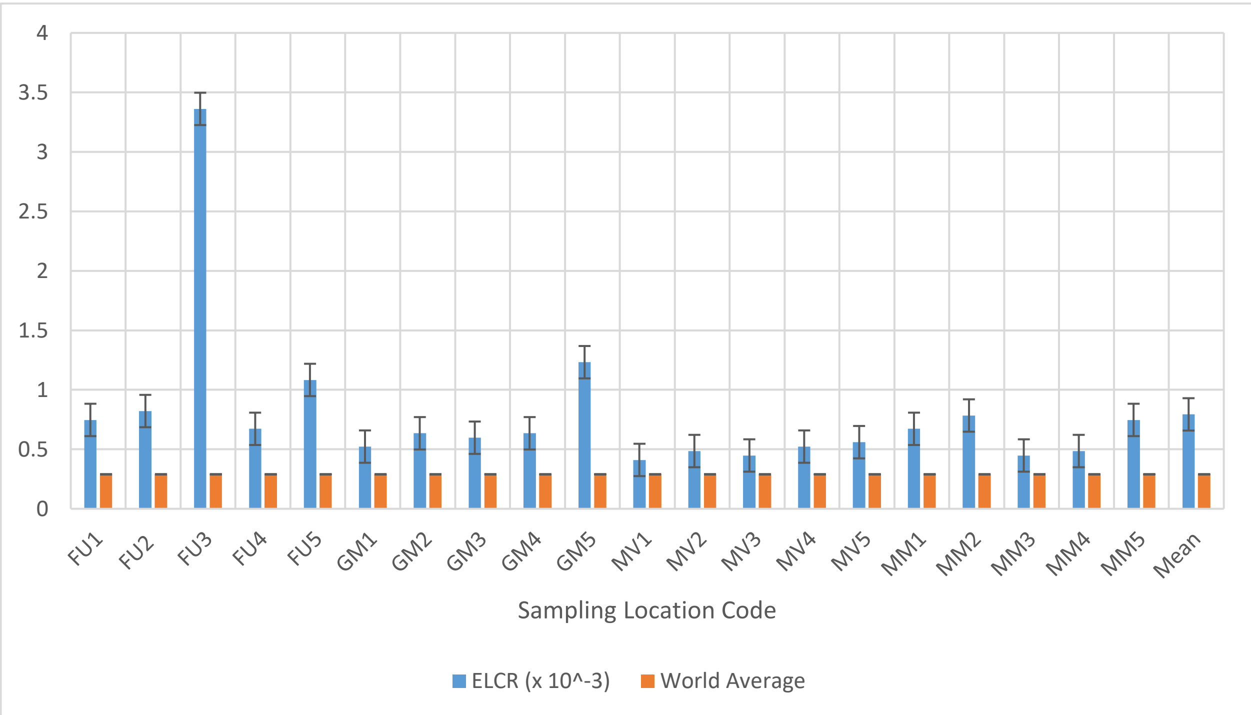

Fig. 2: Comparison between the excess lifetime cancer risk (ELCR) in Lafia Metropolis and world average

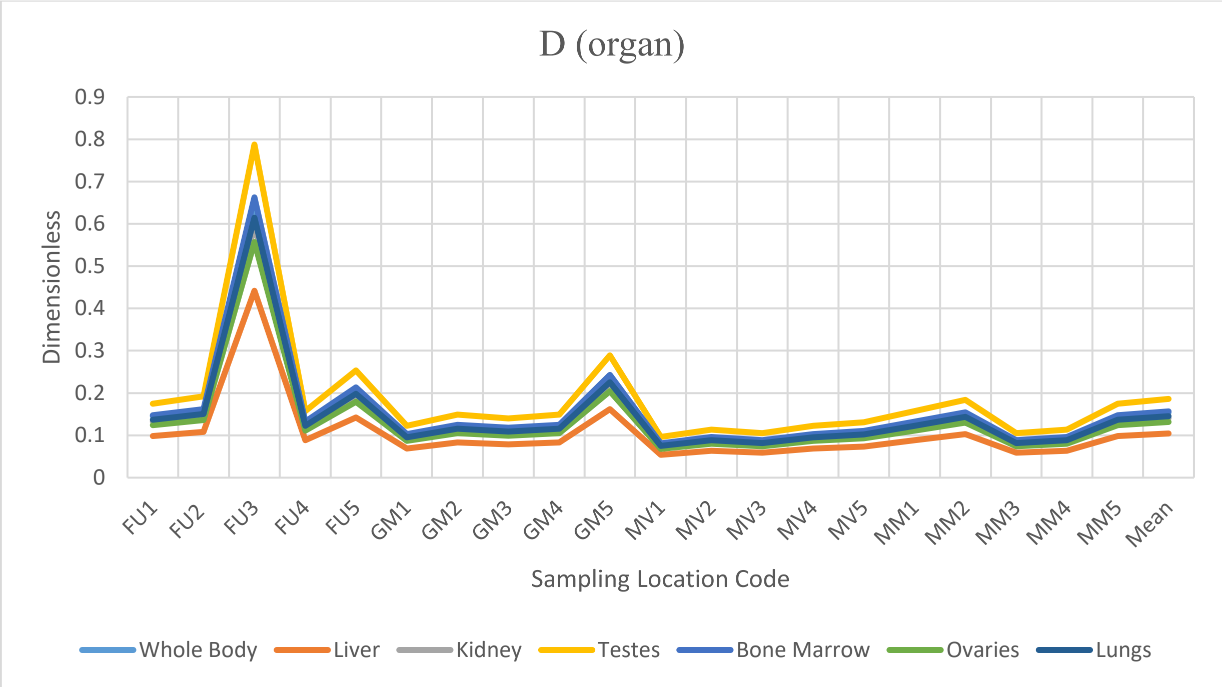

Fig. 3: Comparison of the doses to different body organs

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

The mean D_{organ} values estimated for the whole body, Liver, Kidney, Testes, Bone Marrow, Overies, and Lungs due to exposure and inhalation of radiation in Lafia Metropolis are 0.154, 0.104, 0.141, 0.186, 0.156, 0.132 and 0.145 $mSvy^{-1}$ respectively. In Figure 3, the variation of D_{organ} to the different organs is shown. These results are found to be below the tolerable limits of 1.0 mSv annuall (Agbalagba, Avwiri & Ononugbo, 2016) which indicate that the radiation levels do not constitute any immediate health effect on residents of the study location. From the results, it is concluded that the testes and bone Liver have the highest and lowest sensitivity to radiation respectively. Similar conclusion was reached by Ugbede & Benson (2018); Agbalagba, Avwiri & Ononugbo (2016) and Darwish et al (2015).

3.5 Excess lifetime cancer risk ELCR

The highest and lowest of calculated values of ELCR are 0.411×10^{-3} to 3.360×10^{-3} respectively with mean value of 0.794×10^{-3}. This mean value is higher than the world average value of 0.29×10^{-3}. This lifetime cancer risk is quite high and the possibilities of cancer development by residents who wish to spend all their life time in the area is imminent. The ELCR values reported in this study is lower than those reported by Uburu Salt Lake environments of Ebonyi State, Nigeria reported by Avwiri, Nwaka & Ononugbo (2016) and Agbalagba, Avwiri & Ononugbo (2016) in industrial areas of Warri Nigeria and also lower than those for Okposi Okwu Salt Lake.

4. Conclusion

This study was carried out to examine the radiological impact of outdoor background radiation of Lafia Metropolis, Nasarawa State, Nigeria. The radiation level investigated in this study are well within the recommended dose limits and are within the world average value reported by ICRP and UNSCEAR. Generally, the study shows that Lafia Metroplis is relatively safe radiologically with little contamination which could be attributed to the geological formation and partly due to human activity 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. The results from this study provides the baseline information for the assessment of any environmental radioactive contamination of the area in foreseeable near future.

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