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ASSESSMENT OF BACKGROUND IONIZATION RADIATION AND ASSOCIATED HEALTH RISK IN OIL-PRODUCING BELT OF ONDO STATE, NIGERIA

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Abstract:
An assessment of background ionization radiation and associated health risk in Oil-Producing Belt of Ondo State, Nigeria was carried out using a well calibrated portable radiation detector (Radalert 100) and GPS (Garmin GPS 72H) for the measurement of the geographical locations. The study covers Ese-Odo and Ilaje Local Government Areas with eight notable communities assessed, and is the longest coastline in the riverine area of the current part of the Niger Delta region of Nigeria which is crisscrossed with oil fields operated by national and multinational companies. The exposure rates ranged from 0.004 ± 0.001 mRh^{-1} (AWY-1) to 0.019 ± 0.001 mRh^{-1} (ARM-4) with overall mean value of 0.011 ± 0.003 mRh^{-1}. The computed absorbed dose rates ranged from 30.45 ± 5.14 nGyh^{-1} (AWY-1) to 163.56 ± 6.62 nGyh^{-1} (ARM-4) with overall mean value of 91.31 ± 26.88 nGyh^{-1}. The estimated overall mean annual effective dose equivalent (AEDE) for the LGAs was 0.14 ± 0.04 mSvy^{-1}, while the overall mean excess lifetime cancer risk (ELCR) was (0.49 ± 0.14) x10^{-3}. The dose received by organs was highest in the testes (0.09 mSvy^{-1}), while the liver had the lowest dose values of 0.05 mSvy^{-1}. Among all the estimated risk parameters, mean absorbed dose rate in Ese-Odo LGA and overall mean ELCR for the study area were higher than the safe world average values while all other risk parameters were found to be below the safe world standards. Hence the exposure may not constitute any immediate health risk to the resident of the study area.

Keywords: Excess Life Cancer Risk, Background Ionizing Radiation, Radalert-100, Exposure Rate, Absorbed dose

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1. Introduction

The petroleum industry is a significant contributor to worldwide energy demand despite the growing emphasis on alternative energy sources (BP, 2019, McKinsey Global Institute, 2019, WEC, 2019). In Nigeria, the most significant chunk of centrally collected revenue at the centre comes from oil and gas, which is in large quantity within the Niger Delta region, thus making the region the most relevant in terms of economic importance (Bababo, 2017).

The riverine communities in Ondo State are areas in the Southern Senatorial District of the State, precisely in the Ese-Odo and Ilaje Local Government Areas. It consists of three major ethnic groups: the Apoi, Arogbo-Ijaw, and Ilaje. Oil and gas-related operations are the most apparent industrial activities within this coastal region of Ondo State (Eneogwe *et al.,* 2021). Based on its geographical and geological profile, these areas qualified Ondo State to be one of the nine oil-producing states, primarily coastal and low-lying, members of the Niger Delta region (Bababo, 2017).

In Nigeria, apart from medical exposure, the petroleum industry is the largest importer and user of radioactive sources, covering both upstream and downstream operations (Elegba, 1993). Human activities especially industrial activities which includes gas flaring in the oil gathering centres, crude oil spills in the oil and gas installations, spills of imported toxic chemicals and radionuclide materials for geological mapping, x-ray welding and well logging and other industrial activities tend to increase the background ionizing radiation levels of the community or city (Agbalagba, 2017).

Kuroda (1991) reported that the background radiation levels are from a combination of terrestrial radionuclides ^{40}K, ^{232}Th and ^{226}Ra. He stated that the level is fairly constant over the world, being 0.008-0.015 mRh^{-1}. However due to the high concentrations of radioactive minerals such as Monozite in the soil within areas such as Brazil, India and China, higher background ionizing radiation is predominant in these areas [Kathren, 1991].

GSJ: Volume 10, Issue 11, November 2022
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Radiation monitoring in the hydrocarbon region of Nigeria is critical because of the health hazards and the environmental impact of ionizing radiation (Chad-Umoren, 2012). Several ionizing radiation surveys have previously been carried out in the Niger Delta region to assess the impact of industrialization on the radiation profile of the region, and a strong correlation has been established between high industrial activities and elevated Background Ionizing Radiation (BIR) levels for parts of the region (Avwiri and Ebeniro, 1998, Chad-Umoren and Briggs-Kamara, 2010).

In public health management of radiation emergencies, one of the essential components of integrated assessment is to quickly and accurately assess and categorize the exposure. Thus, good knowledge of the background radiation level is of great importance (UNSCEAR, 2000). When the measured radiation dose or dose rate is within acceptable limits, the impact of the radiation may be insignificant; moreover, the effects of low-level radiation are not yet completely understood (ICRP, 1990). However, the practices of radiation protection have been developed to ensure that the principle of ALARA guides human radiation exposure (As Low As Reasonably Achievable) (Ramli, 2014).

Amiri *et al*., (2011) studied the natural background gamma ray doses to the population of Caspian coastal provinces in North of Iran, their report indicated that the average dose rate in the area under study was about 60.37 nSv/h (0.0065 mR/h) or 0.53 mSv/yr (Range 30 to 90 nSv/h or 0.26 to 0.79 mSv/yr). No significant difference was found among the doses of the provinces (P=0.237).

In an investigation of the radiological impact of Technically Enhanced Radioactive Materials (TENORMs) in oil fields and wells environments in Romania by Botezatu and Iacob (2004), 0.61 mGy/y (69.63 nGy/h) was reported as the average value of annual absorbed dose rate in air from terrestrial gamma radiation. The result was found to be smaller than those related to the other non-nuclear industries (0.72 mGy/y for Coal Fired Power Plants and 0.64 mGy/y for Phosphate Fertilizer Plant). They also concluded that these values are comparable with the annual average absorbed dose rate value of 0.52 mGy/y in air from terrestrial gamma radiation in Romania.

Avwiri *et al*., (2009), investigated terrestrial radiation during production and off-production periods around oil and gas facilities In Ughelli, Nigeria. They reported that the mean radiation levels during production periods ranged from 15.50±1.65 μR/h (0.026±0.003 mSv/wk) to 19.14±3.16 μR/h (0.32±0.005 mS/wk) and from 13.38±1.69 μR/h (0.023±0.003 mSv/wk) to 16.29±2.60 μR/h (0.027±0.004 mSv/wk) during the off-production periods. Therefore, it was observed that the radiation levels of this oil and work environments are higher during production than during off-production periods. Furthermore, the values for both periods were within the safe radiation limit of 0.02 mSv/wk as recommended by the UNSCEAR, but the exposure rates were far above the standard background level of 13.0 μR/hr, indicating a measure of radiation health hazard in the studied locations.

Similarly, evaluation of health risks from exposure to low levels of ionizing radiation in some oil-spilt communities of Rivers State, Nigeria was carried out by Ovuomarie-Kevin *et al*., (2018). Their report indicated that the chance of contracting cancer by residents of the study is low, and the effective dose from the estimated exposure rate to the adult organs investigated was insignificant.

GSJ: Volume 10, Issue 11, November 2022
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In evaluating the Background Ionizing Radiation Level of Selected Oil Spilt Communities of Delta State, Nigeria, Audu *et al*., (2019) reported that all the mean values of absorbed dose, annual effective dose and excess lifetime cancer risk exceeded their recommended safe values. Although the results obtained in their work may not constitute any immediate health risk to the residents of the selected oil spilt communities, long-term exposure in the area may lead to detrimental health risks.

Haghparast *et al*., (2020) carried out assessment of BIR in Hormozgan and Sistan-Bluchestan provinces, southeast of Iran. Their results showed the maximum and minimum absorbed dose rates as 71.9 and 34.2 $nGy.h^{-1}$ in Abomoosa and Minab in Hormozgan province and 90.0 and 47.8 $nGy.h^{-1}$ in Zahedan and Chabahar in Sistan-Bluchestan province, respectively. Data indicated that these areas had a lower BIR level compared with the worldwide level. However, they concluded that the Excess Life Cancer Risk (ELCR) estimated from Annual Effective Dose (AED) was larger compared with the worldwide average of 0.29×10^{-3}.

Rapid *in-situ* radiometric assessment of the Mrima-Kiruku high background radiation anomaly complex of south coastal Kenya was carried out by Kaniu *et al*., (2018). Their report indicated that Absorbed Dose-Rates (ADR) in air ranged from 60–2368 nGy h^{-1}. While Pérez *et al*., (2018) assessed natural background radiation in one of the highest regions of Ecuador where the most distant point to the center of the planet is located. In the study, area measurements of exposure rates showed that values ranged from 0.57 mSv y^{-1} to 3.09 mSv y^{-1} within the region, with a mean value of 1.57mSvy^{-1} (0.019mR/h).

A study on the outdoor ambient radiation and its associated radiological risk parameters on coastal communities of Ndokwa East, Delta State Nigeria was carried out by Ononugbo and Nte, (2017). Their report showed that those coastal communities have been radiologically polluted by the oil and gas activities and farming practices in the area. Though the values obtained may not cause immediate health problems there is a probability of long-term health risk on the residents of the studied communities.

Oil exploration and exploitation in the Niger Delta region of Nigeria and by extension in the oil-producing belt of Ondo state, have evolved over a long history. However, they have left a trail of woes in their path with so much damage to the ecosystem and perceived radiological problems to human life (Bayode, *et al*., 2011). Evaluation of health-related risk from exposure to background ionizing radiation is of immense importance because it will give the radiological status of the area and residents which serves as a radiation safety monitoring tool.

More so, there is a scarcity of information on radiation health risks from terrestrial radioactivity within the study area. In this regard, this study appraises the radiological health risk parameters and effective doses to different body tissues and organs with an intention to report the radiological impact due to oil and gas and its ancillary services on residents in the study area.

2. Materials and methods

2.1 Study Area

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186
The Oil-Producing Belt of Ondo State Nigeria as shown in Figure 1, comprised Ilaje and Ese-Odo Local Government Areas. It lies within the eastern Dahomey Basin and is the longest coastline in the riverine area of the current part of the Niger Delta region of Nigeria. It is bounded to the north by an extensive river (fresh water and marine water) flood plain, a low-lying area with heights not more than 3.5 m above sea level and southward to the land. Oil was first discovered in Nigeria within this region, precisely in Araromi (Sea Side), by a German company, the Nigerian Bitumen company, who unsuccessfully drilled fourteen wells in the area between 1908 and 1914 (NNPC, 2004). Oil exploration and production started in the area in the 1960s; Gulf Oil Company then initiated it, these exploration activities involve using radioactive materials of different forms, strengths and half-lives. The region's initial locations of the exploration exercise were Awoye, Ojumole, Odofado, Molutehin and Oba-nla (Bayode *et al*., 2011). By 2005, six oil companies were exploring within the region namely; Chevron-Texaco Nigeria Limited, Shell Petroleum Development Company, Chronicle, Express Oil, Consolidated Oil and Allied Energy. Due to the presence of these several oil companies, a wider area has been covered by some physical development compared with what used to be in the 1960s and 1970s. There are several oil fields within the study area as at present, out of which 14 belong to Chevron-Texaco Nigeria Limited. Despite various measures that might be put in place by the oil industries to ensure safety in their exploration and exploitation activities, there are possibilities of accidental discharges and leakages of the radioactive material into the environment, which can potentially elevate the level of Background Ionizing Radiation.

GSJ: Volume 10, Issue 11, November 2022
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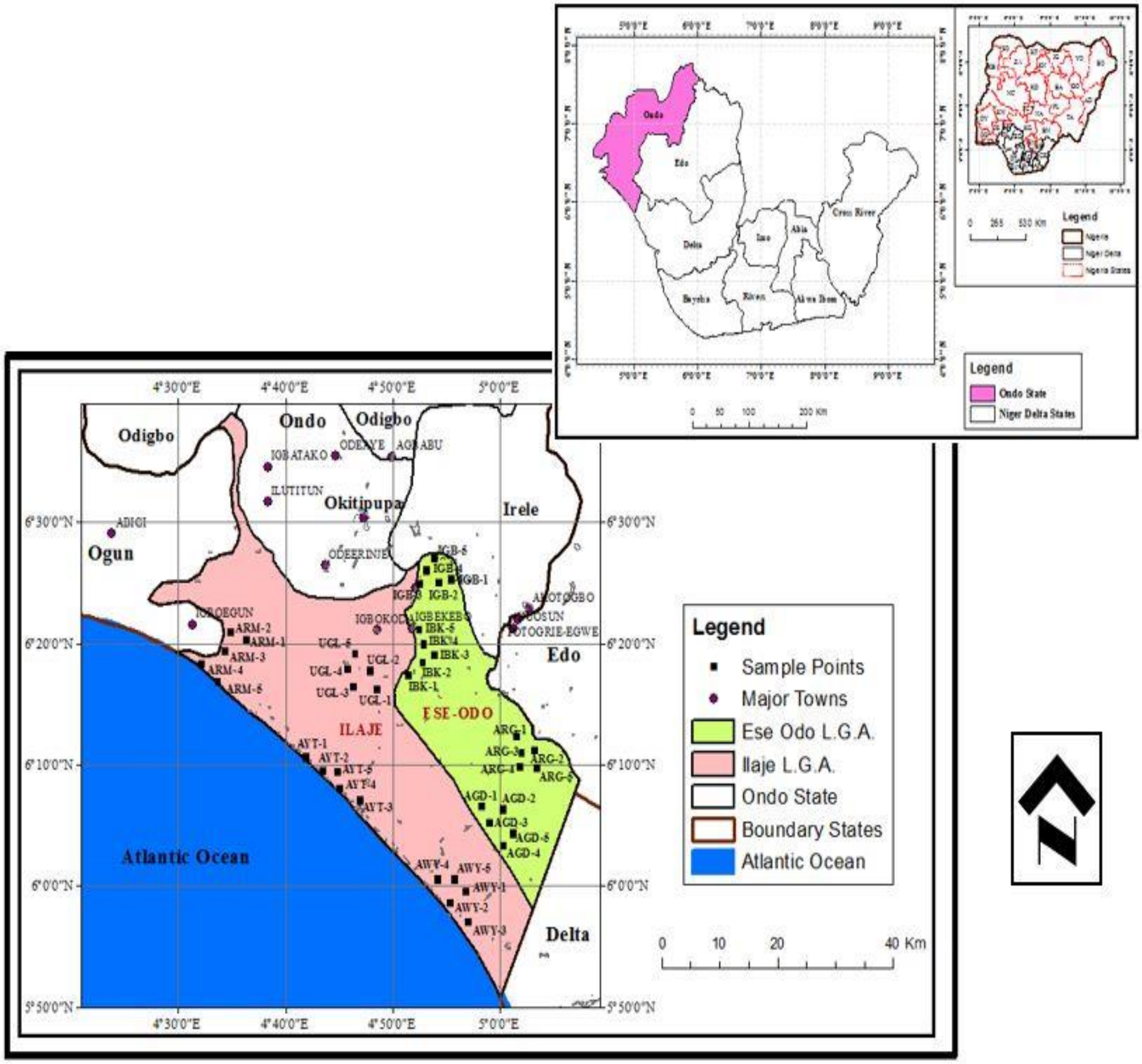

Fig. 1: Map of the Study Area showing Sampling Points

2.2 Method

An *in-situ* background ionizing radiation measurement approach was adopted to enable samples maintain their original environmental characteristics (Ovuomarie-kevin *et al*., 2018). The measurements were carried out using a well-calibrated portable radiation detector (Radalert 100). In addition, a geographical positioning system (Garmin GPS 72H) was used to measure the precise longitude and latitude of the sampling point. The radiation monitor was calibrated at the environmental laboratory of the National Institute of Radiation Protection and Research, University of Ibadan and set to measure exposure rate (in milli Sivert per hour mSvhr^{-1}) and Count Rate (in Count per Minute CPM). Readings were obtained between the hours of 1300 and 1600

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186
since the exposure rate meter has a maximum response to environmental radiation within these hours (Audu *et al*., 2019).

3. Radiological Risk Parameters

3.1 Absorbed Dose Rate

It is defined as a measure of the amount of energy (radionuclides) deposited by ionizing radiation in the human body for a given period (Audu *et al*., 2019). The data obtained for the external exposure rate in μRh^{-1} was converted into absorbed dose rate using the conversion factor as shown in equation 1 (Rafique *et al*., 2014)

$$1\ \mu Rh^{-1} = 8.7\ nGyh^{-1} = 8.7 \times 10^{-3} / \left(\frac{1}{(8760y)}\right), \quad (1)$$

$$1\ \mu Rh^{-1} = 76.212\ \mu Gyy^{-1}$$

3.2 Equivalent Dose Rate

The biological effects per unit dose can be accounted by equivalent dose, hence in the determination of the whole-body equivalent dose rate over one-year period, the recommendation made by National Council on Radiation Protection (NCRP) can be used (Esendu *et al*., 2021). Thus, the exposure rate in mRh^{-1} was converted into equivalent dose rate using the relationship given in equation 2.

$$1mRh^{-1} = \frac{0.96\ x\ 24\ x\ 365}{100}\ mSvy^{-1} \quad (2)$$

3.3 Annual Effective Dose Equivalent (AEDE)

To calculate the annual effective dose equivalent (AEDE) received by residents living in the study area, the computed absorbed dose rates were used. For the calculation of the AEDE, a dose conversion coefficient of 0.7 Sv/Gy recommended by the UNSCEAR for the conversion from absorbed dose in air to effective dose received by adults was used (Agbalagba *et al*., 2016). Meanwhile occupancy factor for outdoors of 0.25 (6 hours out of 24 hours) was also used, while 8760 h is the conversion of 1 year to hours. The annual effective dose was estimated using the relationship in equation 3 (Ovuomarie-kevin *et al*., 2018):

$$\text{AEDE (outdoor) } (mSvy^{-1}) = \text{Absorbed dose } (nGyh^{-1}) \times 8760h \times (0.7Sv/Gy) \times 0.25 \quad (3)$$

3.4 Excess Lifetime Cancer Risk (ELCR)

The Excess Lifetime Cancer Risk (ELCR) is used to estimate the probabilities of contacting cancer by the residents of the study area who will spend all their life time in this environment even in the absence of radioactive components outbreak. From evidence, the Linear No Threshold (LNT) hypothesis extrapolation supported high dose effects to low dose responses claims that all acute ionizing radiation exposures down to zero are harmful. The harm is proportional to the dose and is cumulative throughout life, regardless of how low the dose rate is (Arogunjo *et al*., 2004). We based this study on the traditional worldwide radiation protection standards for late (stochastic) effects which are based on the LNT hypothesis, this implies the probability of residents and

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186
workers in the various communities developing cancer. The Excess Lifetime Cancer Risk (ELCR) was estimated based on the computed values of AEDE, using equation 4 (Avwiri *et al*., 2017):

$$ELCR = AEDE \times Average\ duration\ of\ life\ (DL) \times Risk\ factor\ (Rf) \quad (4)$$

where AEDE is the annual effective dose equivalent, DL is duration of life or man life expectancy (70 years) and RF is the risk factor for fatal cancer risk per Sievert (Sv−1). For low dose background radiations which are considered to produce stochastic effects, ICRP 60 uses a risk factor (RF) value of 0.05 Sv^{-1} for public exposure (Avwiri *et al*., 2017).

3.5 Effective Dose Rate D_{organ} in $mSvy^{-1}$ to Different Organs and Tissues

The effective dose rate for different organs and tissues is calculated using equation 5 (Zaid *et al*., 2010).

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

where AEDE is the annual effective dose equivalent, O is the Occupancy factor of 0.8, and F is the conversion factor for organ dose from ingestion. Conversion factor (F) values for lungs, ovaries, bone marrow, testes, kidney, liver and whole body are 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively as obtained from ICRP (Arogunjo *et al*., 2004, UNSCEAR, 2000).

4. Results and Discussion

Tables 1 to 3 show the *in-situ* exposure rates and the estimated radiological parameters of the various communities in the study area. Figures 2 to 7 show the estimated exposure rates, absorbed dose rates and excess lifetime cancer risk of the sampled communities. The Effective Organ Dose (D_{organ}) Distribution in $mSvy^{-1}$ to different organs and tissues of residents in communities within the Oil and Gas Belt of Ondo State, Nigeria is shown in Figure 8, while contour maps of Ilaje and Ese-Odo LGAs are presented in Figures 9 and 10

Table 1: The mean radiation exposure rate and estimated radiation risk parameters in Ese-Odo Local Government Area

S/N	Location	Geographical Position		Av. Bgrd. (mR/hr)	ADR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR X 10^{-3}	EDR ($mSvy^{-1}$)
1.	IBK-1	6°21.513N	4°51.883E	0.013	112.23	0.172	0.602	1.085
2.	IBK-2	6°22.024N	4°53.054E	0.013	113.10	0.173	0.607	1.093
3.	IBK-3	6°22.908N	4°52.863E	0.014	120.93	0.185	0.649	1.169
4.	IBK-4	6°22.643N	4°53.591E	0.012	104.40	0.160	0.560	1.009
5.	IBK-5	6°21.188N	4°51.652E	0.016	140.94	0.216	0.756	1.362
6.	ARG-1	6°15.730N	5°00.012E	0.012	105.27	0.161	0.565	1.018
7.	ARG-2	6°14.915N	4°60.099E	0.010	83.52	0.128	0.448	0.807
8.	ARG-3	6°15.832N	4°59.924E	0.007	63.51	0.097	0.341	0.614
9.	ARG-4	6°14.572N	4°60.313E	0.010	88.74	0.136	0.476	0.858
10.	ARG-5	6°15.640N	4°59.988E	0.008	66.12	0.101	0.355	0.639
11.	AGD-1	6°18.372N	4°58.196E	0.010	85.26	0.131	0.457	0.824
12.	AGD-2	6°19.598N	4°58.001E	0.011	94.83	0.145	0.509	0.917
13.	AGD-3	6°20.533N	4°58.113E	0.011	92.22	0.141	0.495	0.891
14.	AGD-4	6°20.113N	4°58.227E	0.010	88.74	0.136	0.476	0.858

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

15.	AGD-5	6º21.113N	4º58.172E	0.012	102.66	0.157	0.551	0.992
16.	IGB-1	6º30.306N	4º49.458E	0.012	102.66	0.157	0.551	0.992
17.	IGB-2	6º30.006N	4º49.758E	0.013	111.36	0.171	0.598	1.076
18.	IGB-3	6º30.759N	4º49.136E	0.014	121.80	0.187	0.654	1.177
19.	IGB-4	6º34.026N	4º50.127E	0.010	88.74	0.136	0.476	0.858
20.	IGB-5	6º30.159N	4º49.636E	0.015	129.63	0.199	0.696	1.253
			Mean Value	**0.012 ± 0.002**	**100.83 ± 16.81**	**0.15 ± 0.03**	**0.54 ± 0.09**	**0.98 ± 0.16**

ADR = Absorbed Dose Rate, **AEDE** = Annual Effective Dose Equivalent, **EDR** = Equivalent Dose Rate, **ELCR** = Excess Lifetime Cancer Risk

Table 2: The mean radiation exposure rate and estimated radiation risk parameters in Ilaje Local Government Area

S/N	Location	Geographical Position		Av. Bgrd. (mR/hr)	ADR ($nGyh^{-1}$)	AEDE ($mSvy^{-1}$)	ELCR X 10^{-3}	EDR ($mSvy^{-1}$)
1.	AWY-1	5º54.385N	4º58.791E	0.004	30.45	0.047	0.165	0.297
2.	AWY-2	5º54.276N	4º58.853E	0.008	69.60	0.107	0.375	0.676
3.	AWY-3	5º54.912N	4º58.413E	0.007	58.29	0.089	0.310	0.559
4.	AWY-4	5º54.594N	4º58.674E	0.006	53.07	0.081	0.285	0.514
5.	AWY-5	5º55.284N	4º58.082E	0.006	49.59	0.076	0.265	0.478
6.	AYT-1	6º06.430N	4º46.817E	0.008	69.60	0.107	0.375	0.676
7.	AYT-2	6º06.502N	4º46.957E	0.007	62.64	0.096	0.335	0.603
8.	AYT-3	6º07.661N	4º46.987E	0.007	64.38	0.099	0.345	0.622
9.	AYT-4	6º06.463N	4º46.887E	0.008	72.21	0.111	0.385	0.694
10.	AYT-5	6º08.286N	4º47.009E	0.010	88.74	0.136	0.475	0.856
11.	UGL-1	6º09.959N	4º47.633E	0.014	122.67	0.188	0.660	1.190
12.	UGL-2	6º09.226N	4º47.387E	0.010	88.74	0.136	0.475	0.856
13.	UGL-3	6º08.753N	4º47.596E	0.012	103.53	0.159	0.555	1.001
14.	UGL-4	6º08.472N	4º47.676E	0.011	92.22	0.141	0.495	0.892
15.	UGL-5	6º08.648N	4º47.646E	0.009	76.56	0.117	0.410	0.739
16.	ARM-1	6º20.252N	4º29.334E	0.014	118.32	0.181	0.635	1.145
17.	ARM-2	6º19.830N	4º29.620E	0.012	103.53	0.159	0.555	1.001
18.	ARM-3	6º16.157N	4º42.447E	0.009	78.30	0.120	0.420	0.757
19.	ARM-4	6º19.467N	4º29.087E	0.019	163.56	0.251	0.881	1.586
20.	ARM-5	6º19.572N	4º29.346E	0.008	69.60	0.107	0.375	0.676
			Mean Value	**0.009 ± 0.003**	**81.78 ± 24.65**	**0.13 ± 0.04**	**0.44 ± 0.13**	**0.79 ± 0.24**

ADR = Absorbed Dose Rate, **AEDE** = Annual Effective Dose Equivalent, **EDR** = Equivalent Dose Rate, **ELCR** = Excess Lifetime Cancer Risk

Table 3: Effective dose rate to different organs / tissues

S/N	Communities	AEDE ($mSvy^{-1}$)	Lungs	Ovaries	Bone Marrow	Tastes	Kidney	Liver	Whole Body
1.	Ibekebo	0.18 ± 0.02	0.09 ± 0.01	0.08 ± 0.01	0.10 ± 0.01	0.12 ± 0.01	0.09 ± 0.01	0.07 ± 0.01	0.10 ± 0.01
2.	Arogbo	0.12 ± 0.03	0.06 ± 0.01	0.06 ± 0.01	0.07 ± 0.01	0.08 ± 0.02	0.06 ± 0.01	0.05 ± 0.01	0.07 ± 0.01
3.	Agadagba	0.14 ± 0.01	0.07 ± 0.01	0.07 ± 0.00	0.08 ± 0.01	0.09 ± 0.01	0.07 ± 0.01	0.05 ± 0.00	0.08 ± 0.01
4.	Igbobini	0.17 ± 0.02	0.09 ± 0.01	0.08 ± 0.01	0.09 ± 0.01	0.11 ± 0.02	0.08 ± 0.01	0.06 ± 0.01	0.09 ± 0.01
5.	Awoye	0.08 ± 0.02	0.04 ± 0.01	0.04 ± 0.01	0.04 ± 0.01	0.05 ± 0.01	0.04 ± 0.01	0.03 ± 0.01	0.04 ± 0.01
6.	Ayetoro	0.11 ± 0.04	0.06 ± 0.02	0.05 ± 0.02	0.06 ± 0.02	0.07 ± 0.03	0.05 ± 0.02	0.04 ± 0.02	0.06 ± 0.02

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

7.	Ugbonla	0.15 ± 0.03	0.08 ± 0.01	0.07 ± 0.01	0.08 ± 0.01	0.10 ± 0.02	0.07 ± 0.01	0.05 ± 0.01	0.08 ± 0.01
8.	Araromi	0.16 ± 0.06	0.08 ± 0.03	0.08 ± 0.03	0.09 ± 0.03	0.11 ± 0.04	0.08 ± 0.03	0.06 ± 0.02	0.09 ± 0.03
	Mean Value	**0.14 ± 0.03**	**0.07 ± 0.02**	**0.07 ± 0.02**	**0.08 ± 0.02**	**0.09 ± 0.02**	**0.07 ± 0.02**	**0.05 ± 0.01**	**0.08 ± 0.02**

AEDE = Annual Effective Dose Equivalent

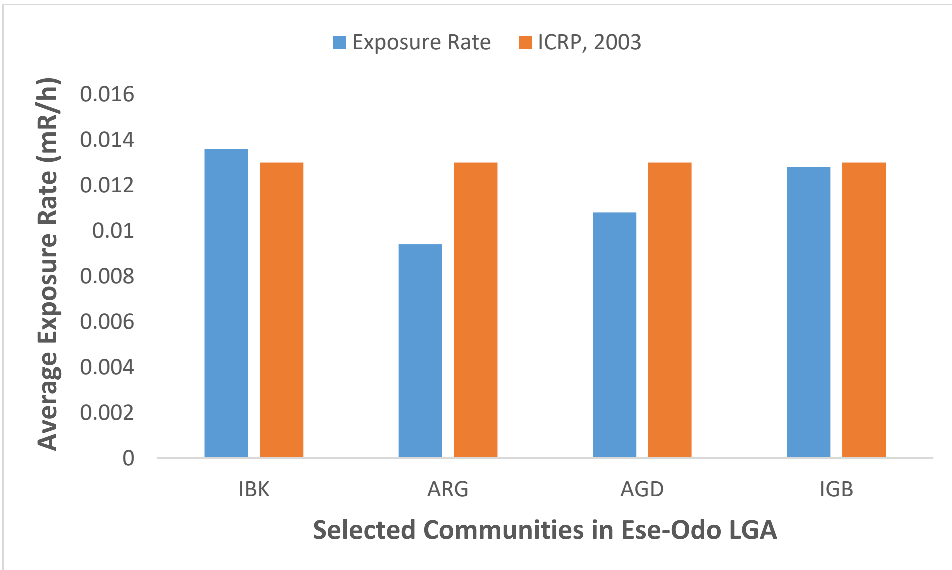

Fig. 2: Comparison of Measured Exposure Rates in Ese-Odo LGA with ICRP Standard

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

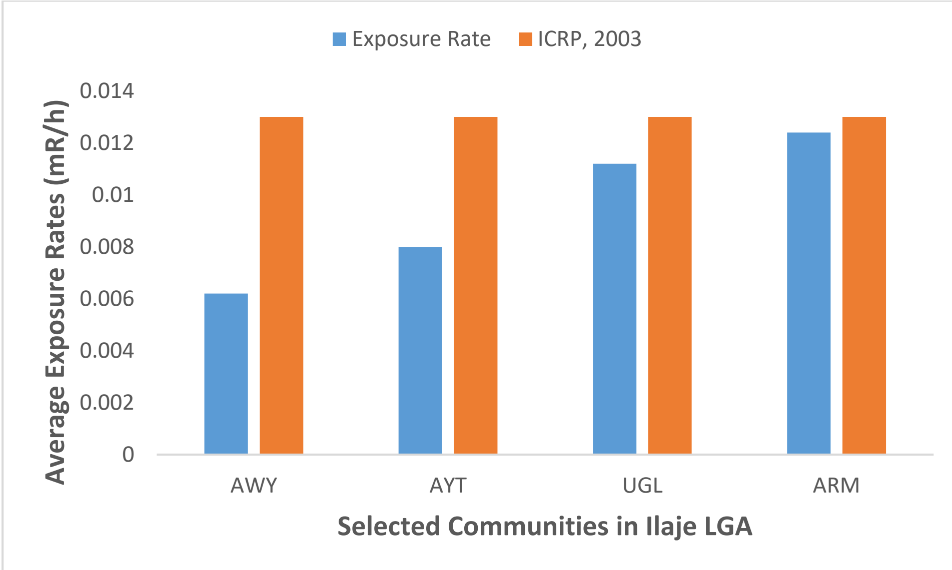

Fig. 3: Comparison of Measured Exposure Rates in Ilaje LGA with ICRP Standard

The range of exposure rate from the eight communities studied (0.004 to 0.019) mRh^{-1} is similar to the fairly constant world's BIR range of 0.008-0.015 mRh^{-1} reported by Kuroda (1991). Similarly, the overall mean exposure rate value of 0.011 mRh^{-1} from these communities, is higher when compared with the average dose rate value of 0.0065 mR/h to the population of Caspian coastal provinces in North of Iran obtained by Amiri *et al*., (2011), but lower than the ICRP standard of 0.013 mR/h (ICRP, 2003), 0.019mR/h (Pérez *et al*., 2018) and the mean BIR values of 0.0156 mR/h from coastal communities in Burutu L.G.A, of Delta State, Nigeria (Avwiri and Esi, 2015) with similar geological ecosystem. This shows that the overall background ionizing radiation levels of the studied communities in the oil-producing belt of Ondo State are not elevated.

The mean absorbed dose rate values are 100.83 $nGyh^{-1}$ and 81.78 $nGyh^{-1}$ for Ese-Odo and Ilaje LGAs, respectively. The overall mean value obtained in Ese-Odo LGA is higher than the permissible world value of 89 $nGyh^{-1}$, while the overall mean values in both LGAs are higher than the maximum and minimum values in Abomoosa and Minab in Hormozgan province south-east of Iran (Haghparast *et al*., 2020) and mean value of 69.63 nGy/h in oil fields and wells environments in Romania (Botezatu and Iacob 2004), but lower than all mean values obtained from solid mineral mining sites in Benue state Nigeria (Olanrewaju and Avwiri, 2017).

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

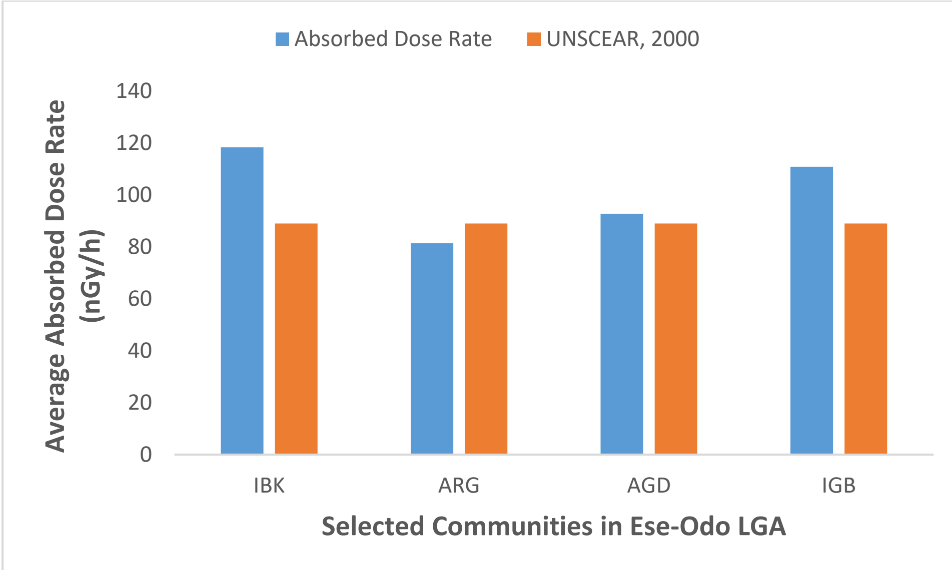

Fig. 4: Comparison of Average Absorbed Dose Rates in Ese-Odo LGA with UNSCEAR Standard

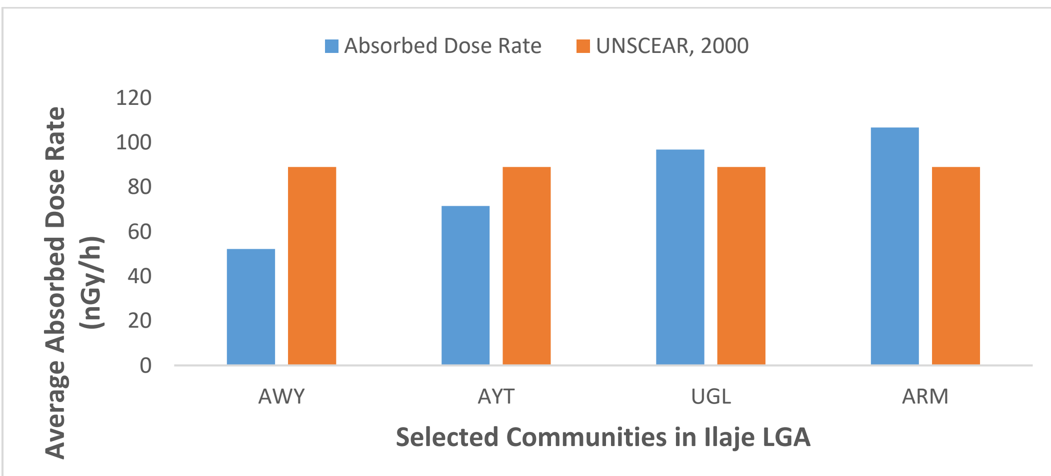

Fig. 5: Comparison of Average Absorbed Dose Rates in Ilaje LGA with UNSCEAR Standard

The average annual effective dose equivalent recorded in the studied communities are 0.18, 0.12, 0.14, 0.17, 0.08, 0.11, 0.15 and 0.16 mSvy^{-1} for Ibekegbo, Arogbo, Agadagba, Igbobini, Awoye, Ayetoro, Ugbonla and Araromi respectively. The estimated mean AEDE values of 0.15 and 0.13 mSvy^{-1} for Ese-Odo and Ilaje LGAs, respectively, were similar to the results obtained from selected oil spill communities of Bayelsa State Nigeria (Ovuomarie-kevin *et al*., 2018) and that reported by Agbalagba, (2017), but are lower than the values arising from environmental gamma radiation in 10 counties of Iran (Toossi *et al*., 2009) and the global world average of 1.0mSvy^{-1} for outdoor environment. These results indicate minimal possible radiological contamination of the sampled sites.

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

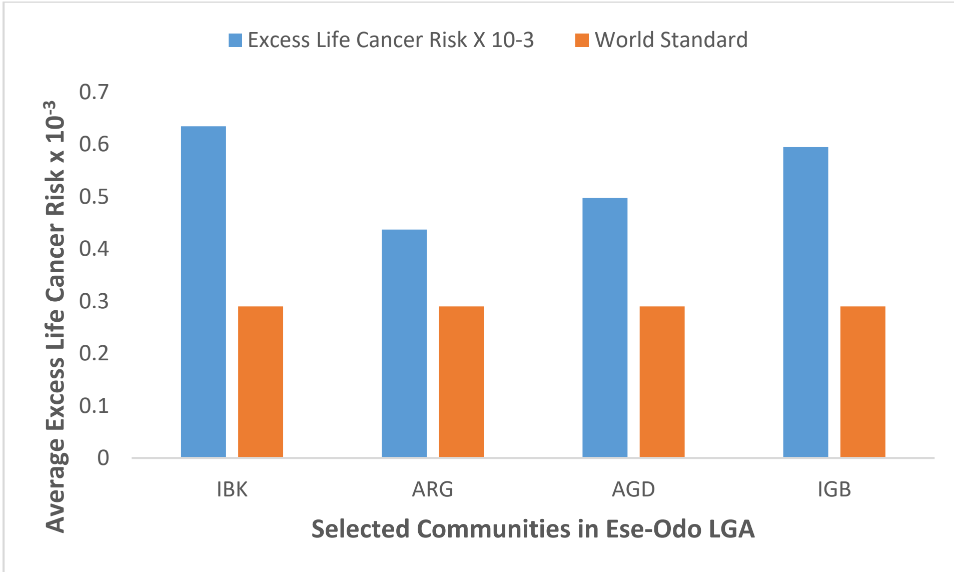

Fig. 6: Comparison of Average ELCR in Ese-Odo LGA with World Safe Limit Value

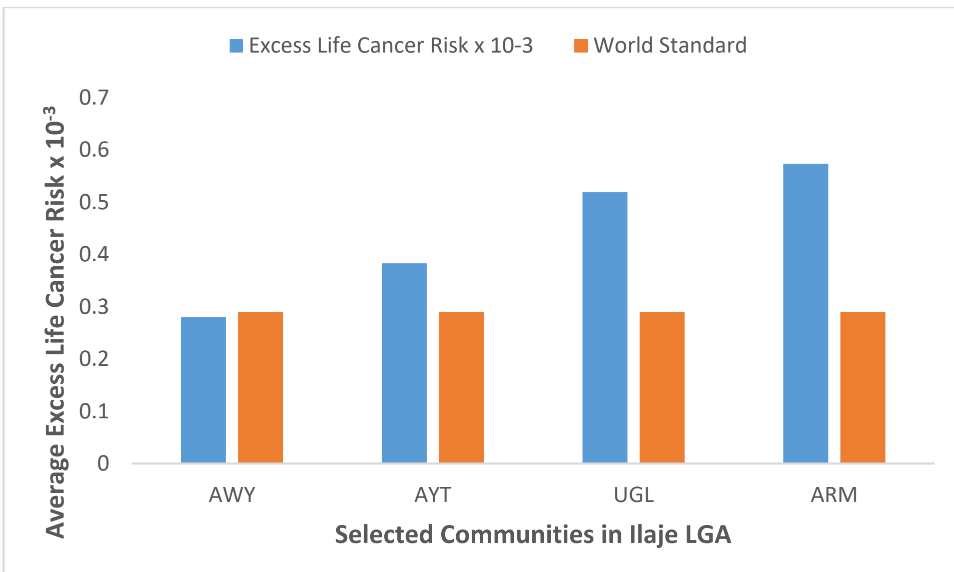

Fig.7: Comparison of Average ELCR in Ilaje LGA with World Safe Limit Val

The mean Excess Life Cancer Risk (ELCR) of 0.54 and 0.44 μSvy^{-1} for the studied communities in Ilaje and Ese-Odo LGAs respectively are higher than the world standard of 0.29 x 10^{-3}. These values are however similar to the mean ELCR for outdoor exposure for Jhelum valley of the state of Azad Kashmir-Pakistan, estimated by Rafique *et al*., (2014). But lower than ELCR values estimated in some Selected Okoroama / Tereke (O/T) South communities of Bayelsa State, Nigeria (Esendu *et al*., 2021) and Selected Oil Spill Communities of Delta State, Nigeria (Audu *et al*., 2019). However, the assessed mean ELCR for the two LGAs in our study implies that residents of the studied communities' chances of contracting cancer over time are probable and individuals exposed to this radiation may be capable of exerting some acute and long-term adverse health effects due to ionization of tissues.

GSJ: Volume 10, Issue 11, November 2022
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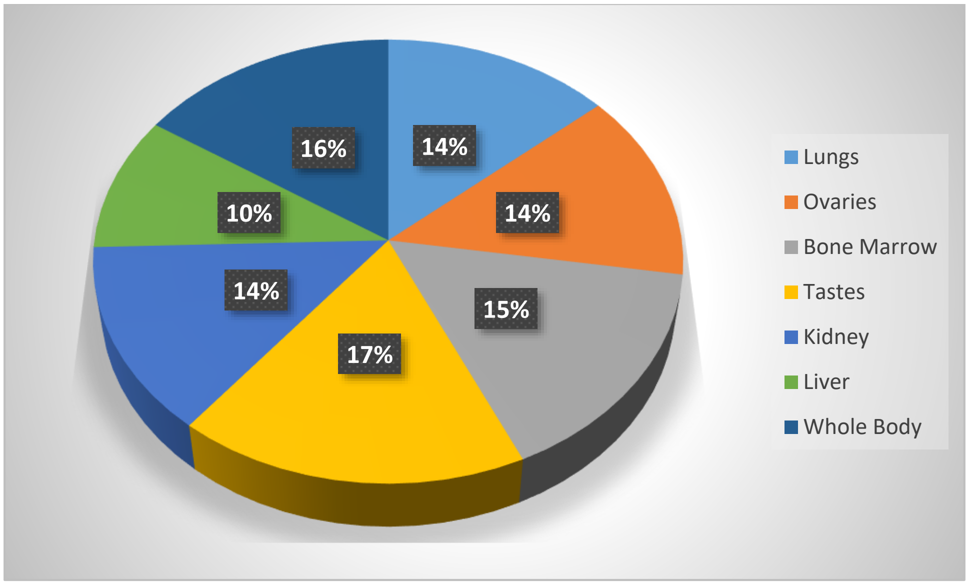

Fig. 8: Effective dose rate to different organs / tissues

The calculated effective dose rates delivered to the different organs in the adult body are shown in table 3 and presented in Figure 8. It was shown that the testes recorded the highest dose of 0.09 mSvy $^{-1}$ while the liver recorded the most negligible value with an average value of 0.05 mSvy^{-1}. These results indicate that the estimated doses to the different organs are below the international tolerance limits on dose to body organs of 1.0 mSvy^{-1}. The relatively higher dose to the testes and low dose intake to the liver is justifiable from the radioactivity distribution pattern (WHO 1993; Zaid *et al*., 2010; Rafique *et al*., 2013). This result shows that exposure to background ionizing radiation levels in all the studied communities contributes insignificantly to the radiation dose to these organs in adults.

GSJ: Volume 10, Issue 11, November 2022
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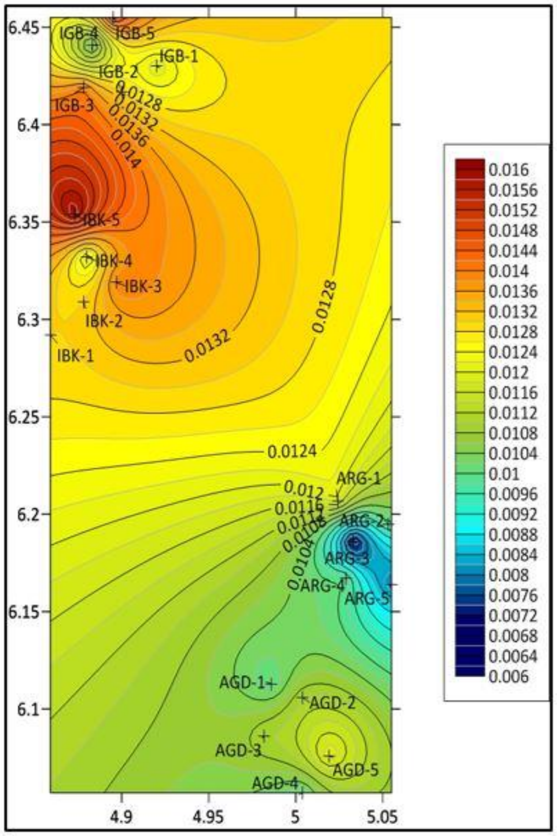

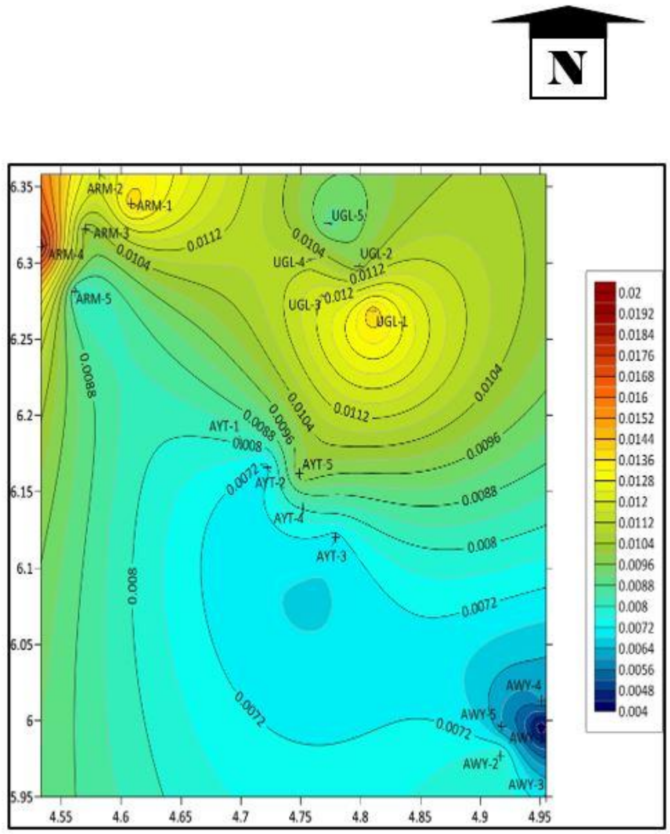

Fig. 9: Contour map of communities in Ese-Odo LGA

Fig. 10. Contour map of communities in Ilaje LGA

Represented in figures 6 and 7 are radiation contour maps of the study area within the Ese-Odo and Ilaje L.G.As. The surface's corresponding slopes are indicated by the contour lines relative spacing and colour variations showing the corresponding distribution of radiation exposure rates from the lowest to the highest values, as depicted in blue and red respectively. Both Ese-Odo and Ilaje region exposure pattern of radiation generally increases from South to North with low-line and evenly spaced gentle slope dominating the areas; and showing low to average radiation exposures in Ilaje, while the Ese-Odo region is characterized by average to high radiation exposures.

5. **Conclusion**

The study of the terrestrial Background Ionizing Radiation levels of eight communities within the Oil and Gas Belt of Ondo State, Nigeria have been carried out in order to estimate the radiological health risk parameters. As a result, the following conclusion was deduced from the present study.

1) The overall mean value of the communities' background ionizing radiation level was lower than the ICRP permissible value.
2) The computed mean absorbed dose rate values of communities in Ese-Odo LGA is higher than the world standard value, while that in Ilaje LGA was found to be lower.

GSJ: Volume 10, Issue 11, November 2022
ISSN 2320-9186

3) The estimated mean AEDE values of communities in both Ese-Odo and Ilaje LGA**s** were lower than the total worldwide average effective dose from natural radiation.
4) The estimated mean excess lifetime cancer risk (ELCR) values of communities in both Ese-Odo and Ilaje LGA**s** were higher than the world standard and there could be a probability of developing cancer over time for residents of these areas.
5) The effective dose delivered to different Organs of the body were calculated, and results obtained in the study area were compared with that of tolerable international limits; results showed that all values obtained were lower.

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