International Journal of Research in Engineering and Science (IJRES)
ISSN (Online): 2320-9364, ISSN (Print): 2320-9356
www.ijres.org Volume 12 Issue 5 ǁ May 2024 ǁ PP. 190-202

Assessment of Radiological Risk in Oil Producing Communities in Bayelsa West Senatorial District, Bayelsa State, Nigeria

[1]MOSES OGHENERUKEVWE OKEVWEMEKE; [1]AREREBO KINGSLEY EGBEJULE; [2]GREGORY O. AVWIRI; [3]EZEKIEL O. AGBALAGA; [4]ONYEKACHI GODWIN ANIEKWE; [5]COLLINS OGHENEJERU AZIKIWE; [5]OLIVIA ENIMOR ODIKI

[1,3,4]Department of Physics, Federal University of Petroleum Resources Effurun, Delta State, Nigeria
[2]Department of Physics, University of Port-Harcourt Rivers State, Nigeria
[5]Department of Mechanical Engineering, Niger Delta University Wilberforce Island
[5]Department of Port Management, Nigerian Maritime University Okerenkoko
Email: oghenerukevwe2050@gmail.com, egbejuleakinsley@gmail.com, goavwiri@yahoo.com, aglagba.ezekiel@fupre.edu.ng, aniekweonyekachi@gmail.com, azikiwecollins9@gmail.com, oenimor@gmail.com

ABSTRACT
A total of one hundred (100) sampled points were investigated for radioactivity level in communities within Bayelsa West Senatorial District, Bayelsa State using a Gamma Scout radiation meter and a Global Positioning System (GPS). The exposure rate ranged from $0.0082 \pm 0.00047 mRh^{-1}$ to $0.013 \pm 0.0032 mRh^{-1}$ with an average value of $0.0106 \pm 0.0017\ mRh^{-1}$. Equivalent Dose rate ranged from $0.690 \pm 0.0395 mSvy^{-1}$ to $1.061 \pm 0.2659 mSvy^{-1}$ with an average value of $0.886 \pm 0.138\ mSvy^{-1}$. The values of the absorbed dose rate (ADR) and annual effective dose equivalent (AEDE) ranged from ($71.38 \pm 4.1144 nGyh^{-1}$) and ($87.55 \pm 5.0467 \mu Svy^{-1}$) to ($109.66 \pm 27.4153 nGyh^{-1}$) and ($134.49 \pm 33.6214 \mu Svy^{-1}$) with average values of $91.610 \pm 14.267 nGyh^{-1}$ and $112.304 \pm 17.441 \mu Svy^{-1}$ respectively. The excess lifetime cancer risk (ELCR) ranged from $0.306\times10^{-3} \pm 0.0179$ to $0.471\times10^{-3} \pm 0.117$ with an average value $0.393\times10^{-3} \pm 0.0615$. The Background Ionizing Radiation (BIR) and Equivalent Dose Rate (EDR) where below their standard limits of $0.013\ mRh^{-1}$ and $1\ mSvy^{-1}$ respectively. The Absorbed Dose Rate (ADR), Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) were above their standard limits of 84 $nGyh^{-1}$, 70 μSvy^{-1} and 0.29×10^{-3} respectively. The results obtained in this work may not constitute any immediate health risk to the residents of the selected oil spill communities but long-term exposure in the area may lead to detrimental health risks.

Date of Submission: 06-05-2024 Date of acceptance: 18-05-2024

I. INTRODUCTION

Natural background radiation exposure is a constant, unavoidable aspect of life on Earth. Cosmic rays and the inherent radioactivity of soil, air, and water are the main contributors to the natural radioactive background. Natural radionuclides such the ^{40}K, ^{232}Th and ^{238}U series nuclides, which are present in trace amounts in all soil layers, are the primary source of environmental radioactivity. Geological and geographic factors play a major role in radioactivity in the natural environment and associated external exposure to gamma rays (UNSCEAR, 2000). The composition of each petrologically distinct location and the kind of parent material from which the soil originated determine the precise concentration of terrestrial environmental radiation. Environmental radionuclides can quickly travel through environmental matrices due to their high geochemical mobilities (Ononugbo *et al.*, 2017).

The construction, exploration, production, downstream, and marketing sectors are all part of the Niger Delta oil and gas business, which has several facets. Radiation generators and radioactive materials are used extensively in the majority of these professions. Industrial radiography, automated radiation monitoring, well logging, radiotracer use, formation mapping and evaluation, and other natural carbonization are a few uses of radioactive materials in the onshore and offshore oil and gas industries consists of hydrogen resource extraction (Avwiri et al., 2007). The manufacturing of kerosene, gasoline, and lubricants for the maintenance of industrial machinery, among other things, all depend on the refinement of oil. However, it is impossible to ignore the negative consequences of the unchecked and unregulated use of this natural resource (crude oil). As technology advances and becomes more widely accepted the demand for crude oil's byproducts rises steadily. As a result, oil and gas businesses continue to explore for, mine, and process petroleum. The outcome of this demand may have had major environmental implications on both workers in related occupations and residents of the areas surrounding these facilities for processing oil and gas. Communities in Bayelsa West Senatorial District in Niger Delta region is one of the largest oil and gas producing communities and have immensely contributed to the growth of Nigeria economy yearly. It is well known that there is an increased risk of developing cancer, leukemia, cataracts, hematological depression, and chromosomal aberrations depending on the dose of radiation exposure from oil and gas facilities (EPA, 2009). This becomes noticeable only many years after the radiation dose (usually he is 10-40 years).

Anekwe *et al.,* (2023) carried out a research on the evaluation of the spatial distribution of environmental radiation in Kolo, Bayelsa State, Nigeria. According to estimates, background ionizing radiation levels and associated equivalent dose rates were $0.019\,\text{mRhr}^{-1}$ and $1.562\,\text{mSvyr}^{-1}$, respectively. The calculated metrics for radiation health risk, such as the absorbed dose rate, the yearly effective dose equivalent, and the excess lifetime cancer risk of $165.30\,\text{nGyh}^{-1}$ $(0.203\,\text{mSvyr}^{-1})$ $(0.711\,\text{mSvyr}^{-1})$, are just a little bit higher than generally accepted limits. They came to the conclusion that the region's persistent pipeline theft and vandalism, which has resulted in oil leaks, as well as oil and gas exploration and production activities may be to blame for the minor rise in background ionizing radiation.

The average value for exposure levels in the research region was $14.47\,\mu\text{Rh}^{-1}$, which is greater than the allowed limit, according to Ononugubo *et al.,* (2017), who conducted an estimate of extra lifetime cancer risk owing to gamma dose rates in coastal areas of Bonny Island, Rivers State, Nigeria as reported.

In a study to evaluate background ionizing radiation levels in central Delta State, Nigeria, Edomi et al. (2020) estimated mean values for BIR-related radiation health markers and discovered that the mean values were low relative to the area. Some communities maintained average values: Ekpan, Jeddo, Ugbokorodo, and Kokori were above the world average. This is a result of the oil and gas development in these areas. However, it has been established that neither the population nor the surveyed areas are overexposed to radiation risks. The environment, however, may be dangerous for people if exposure is prolonged. However, the authorities in charge of regional radiological protection should conduct routine inspections.

The Bayelsa West Senatorial District and the communities around it are a significant oil-producing area in Nigeria's Niger Delta. A system of pipes crosses the area and transports gas and/or oil from numerous locations (wells) to flow stations. There are documented health hazards associated with prolonged background radiation exposure for workers and host communities. There are not many studies on the radioactive background levels in these places. The dependability of this study will be improved by properly documenting background ionizing radiation levels in the area and providing baseline data for follow-up research. The effects of the information gathered on health were also carefully taken into account (Avwiri *et al.,* 2007). The objective of the current study is to evaluate the radiological effects on the population and the environment in the oil and gas producing areas in the Bayelsa West Senatorial District of Nigeria. Additionally, the study will add to the body of knowledge already known about the radiological profile of oil facilities in the area and provide baseline data on the background ionizing radiation (BIR) profile of the flow stations and their host towns. Investigations will be done into the health effects on residents and workers in the host communities.

II. MATERIALS AND METHOD

Study Area

The research area is the Bayelsa West Senatorial District, which includes the Nigerian local governments of Sagbama and Ekeremor. The area has a total land mass of 2771.9 km^2 and is situated between Latitudes $4^0 42'$N and $5^0 23'$N of the Equator and Longitudes $5^0 23'$E to $6^0 32'$E of the Greenwich Meridian (National Population Commission (NPC), 2009). Yenagoa, Kolokuma/Opokuma and Southern Ijaw LGAs border it to the north by Delta State and to the south. On the Bight of Bonny, the research area also features a coastline that extends for around 60 kilometers. Many of the settlements are unreachable by road since they are partially or entirely surrounded by water. The study areas include a few chosen locations in the Bayelsa West senatorial district (Opukushi, Cloughe Creek, Ofoni, Agbere and Tunu) with a focus on oil and gas installations' mining and exploration zones. Oil and gas can move from one station to another due to interconnected networks of pipes buried in the ground and beneath water. A map showing the studied communities is depicted in figure 1.

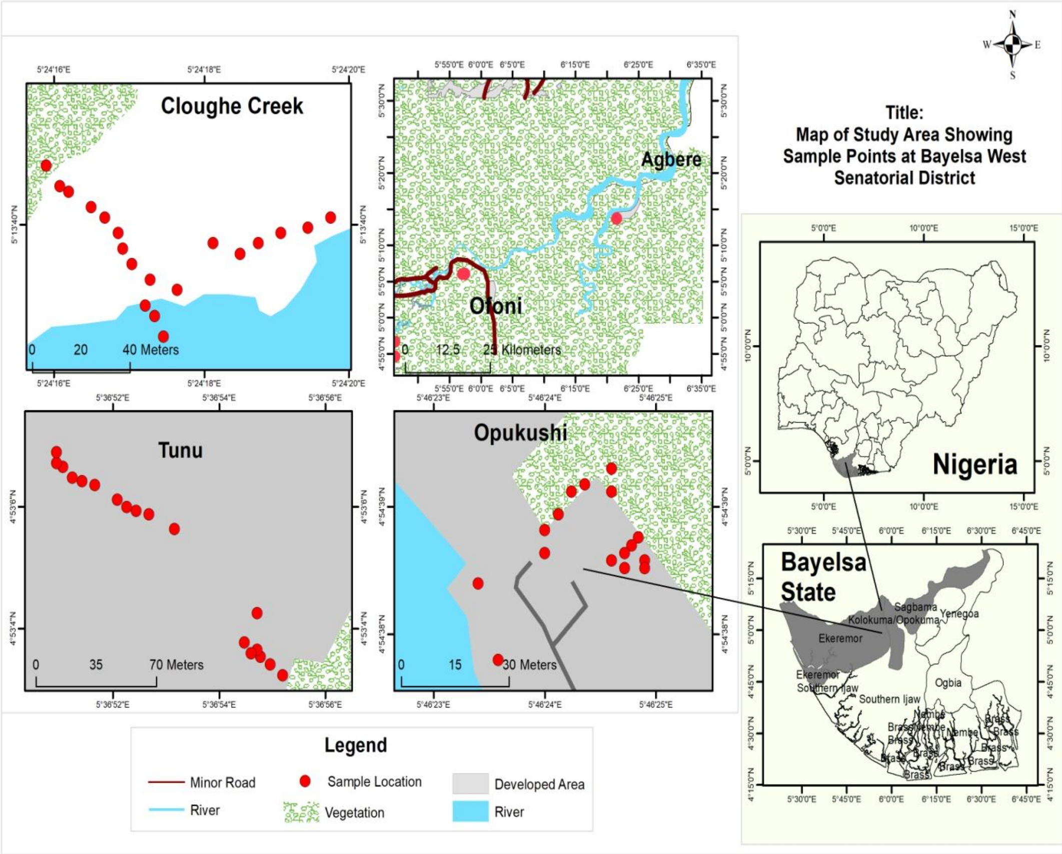

Figure 1: Map of the Study Area Showing Sample Points at Bayelsa West Senatorial district (Okevwemeke et al. 2023).

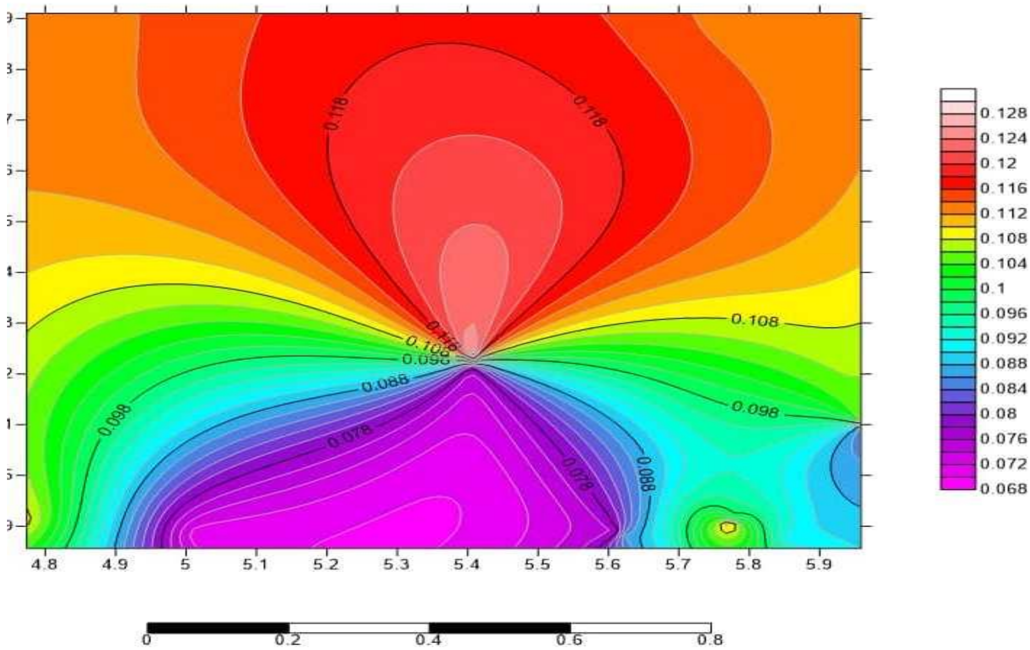

Figure 2 the Contour Map of Oil and Gas fields of the studied communities in Bayelsa West Senatorial District, Bayelsa State

Measurement of Background Ionizing Radiation (BIR): Oil and gas fields in the Bayelsa West Senatorial District of Bayelsa State were measured at key locations. For the purpose of measuring background ionizing radiation *in-situ*, materials were kept in their original ambient conditions. Within the temperature range of 10^0c to 50^0c, a Gamma Scout Radiation Meter with a Geiger-Muller tube that can detect alpha, beta, and gamma readings was employed. A geographical positioning system (GPS) was utilized to determine the exact site of sampling. A properly calibrated Gamma Scout radiation meter (USA standard FFC15) was used to conduct the examination. The meter has a maximum gamma efficiency of 7% and a sensitivity for radiation relative to Co-60 of 95.0 impulses/min. It has a 9.1 mm effective diameter halogen-quenched Geiger-Muller detection tube. The GPS measurement was taken at the location where the radiation monitoring meter's tube was lifted to the standard height of 1.0 m above the ground (Okevwemeke et al. 2023) with its window facing the suspected source. At each sampling site, measurements were taken twenty (20) times to account for environmental parameter variations. Readings were taken between 13:00 and 16:00 hr since, according to the permitted limit; this is when the radiation meter responds to external radiation the most.

The Gamma Scout Meter records the radiation exposure rate in microsieverts per hour (μSvh^{-1}). Millirotegen per hour (mRh^{-1}) was calculated from measurements in μSvh^{-1} using the relationship:

$$\mathbf{1\ \mu Svh^{-1} = 0.107185\ mRh^{-1}} \quad (1)$$

Computation of Equivalent Dose Rate (EDR)

We used the method (3.3) suggested by the National Council for Radiation Protection and Measurements (NCRP) to convert the measured BIR values to absorbed dose rates in order to calculate the one-year equivalent dose rate (Okevwemeke et al. 2023).

$$\mathbf{1\ mRh^{-1} = \frac{0.96 \times 24 \times 365}{100}\ mSvy^{-1} = 84.096\ mSvy^{-1}} \quad (2)$$

Computation of Absorbed Dose Rate (D)

The amount of energy that ionizing radiation deposits in a medium per unit mass is known as the absorbed dose. It can be expressed in the appropriate SI unit, gray (Gy), or rad, and measured in joules per kilogram.

Using Okevwemeke et al. (2023), radiation exposure values measured in the study region were also converted to absorbed dose rates (Gyy^{-1}). First, we must apply the following equation to change the value of mRh^{-1} to μRh^{-1} :

$$\mathbf{1\ mRh^{-1} = \ 0.001\ \mu Rh^{-1}} \quad (3)$$

$$\mathbf{1\mu Rh^{-1} = 8.7 nGyh^{-1} = \frac{8.7 \times 10^{-3}}{\frac{1}{8760y}} \mu Gyy^{-1} = 76.212 \mu Gyy^{-1}} \quad (4)$$

Computation of Annual Effective Dose Equivalent (AEDE)

According to Avwiri et al. (2014), the annual effective dosage that a member of the public receives indoors and outdoors is estimated from the absorbed dose rate using a dose conversion factor of 0.7Sv/Gy and occupancy factors of 0.2 and 0.8, respectively. The following formulae are used to calculate AED.

$$\mathbf{AED_{outdoor}(\mu Svy^{-1}) = D(nGyh^{-1}) \times 8760h \times 0.7\ (SvGy^{-1}) \times 0.2 \times 10^{-3}} \quad (5)$$

In comparison to the default AEDE (indoor), which is 450 Svy^{-1}, the default AEDE (outdoor) is 70 Svy^{-1}. These indices evaluate the likelihood that exposed individuals would experience both probabilistic and deterministic effects (Uyo, 2015).

Computation of Excess Lifetime Cancer Risk (ELCR)

The term "excess lifetime cancer risk" refers to the risk of developing cancer over the course of a lifetime that is greater than the "natural" background risk. In reality, exposure does not last a lifetime, competing causes are prevalent, there are typically multiple carcinogens present in the exposure, and therapy has the potential to significantly lower the chance of dying from cancer.

The following equation (Agbalagba et al. 2017) is used to determine the Excess Lifetime Cancer Risk (ELCR):

$$\mathbf{ELCR = AEDE \times DL \times RF} \quad (6)$$

Where, AEDE is the Annual Equivalent Dose Equivalent, DL is the average duration of life (estimated to 70 years), and RF is the Risk Factor(Sv^{-1}), i.e. fatal cancer risk per Sievert. According to Taskin et al. (2009), the ICRP adopts RF as 0.05 for public stochastic effects with 0.29×10^{-3} been the Excess Lifetime Cancer Risk UNSCEAR standard.

III. RESULTS AND DISCUSSION

Results

Table 1 to Table 5, report the findings of the background ionizing radiation at several sampled communities and the accompanying estimated radiological health risk parameters for the communities in Bayelsa West Senatorial District. Table 6 shows the average mean values of the sampled area. The Background Ionizing Radiation (BIR) level and calculated radiological health risk parameters were plotted against their standard values respectively as shown in Figure 3 to Figure 7.

The investigation of several parameters was done to analyze health indices. The health implications of residing in those communities were made known because of the radiation level being determined in this regard. This was carried out in accordance with accepted practice and standards, which also produced positive outcomes in related studies conducted in various locations, such as in Avwiri et al., 2013. The following hazard indices were estimated in order to complete the investigation: Equivalent Dose Rate (EDR), Absorbed Dose Rate (ADR), Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR).

Table 1: Measured exposure rate and calculated hazard indices in Opukushi community

S/NO	GPS	BIR μSvh^{-1}	BIR (mRh^{-1})	EDR ($mSvy^{-1}$)	ADR ($nGyh^{-1}$)	AEDE (μSvy^{-1})	ELCR $\times 10^{-3}$
1	$N04^0 54.630'$ $E005^0 46.393'$	0.110	0.0118	0.99	102.66	125.90	0.441
2	$N04^0 54.644'$ $E005^0 46.400'$	0.108	0.0116	0.98	100.92	123.77	0.441
3	$N04^0 54.647'$ $E005^0 46.400'$	0.105	0.0113	0.95	98.31	120.57	0.433
4	$N04^0 54.649'$ $E005^0 46.402'$	0.102	0.0109	0.92	94.83	116.30	0.407
5	$N04^0 54.652'$ $E005^0 46.404'$	0.101	0.0108	0.91	93.96	115.23	0.403
6	$N04^0 54.653'$ $E005^0 46.406'$	0.098	0.0105	0.88	91.35	112.03	0.392
7	$N04^0 54.655'$ $E005^0 46.410'$	0.099	0.0106	0.89	92.22	113.10	0.396
8	$N04^0 54.652'$ $E005^0 46.410'$	0.100	0.0107	0.90	93.09	114.17	0.400
9	$N04^0 54.649'$ $E005^0 46.411'$	0.104	0.0111	0.93	96.57	118.43	0.415
10	$N04^0 54.647'$ $E005^0 46.413'$	0.102	0.0109	0.92	94.83	116.30	0.407
11	$N04^0 54.647'$ $E005^0 46.413'$	0.105	0.0113	0.95	98.31	120.57	0.421
12	$N04^0 54.646'$ $E005^0 46.414'$	0.104	0.0111	0.93	96.57	118.43	0.415
13	$N04^0 54.645'$ $E005^0 46.413'$	0.102	0.0109	0.92	94.83	116.30	0.407
14	$N04^0 54.644'$ $E005^0 46.412'$	0.108	0.0116	0.98	100.92	123.77	0.433
15	$N04^0 54.643'$ $E005^0 46.414'$	0.110	0.0118	0.99	102.66	126.22	0.442
16	$N04^0 54.643'$ $E005^0 46.415'$	0.109	0.0117	0.98	101.79	124.84	0.437
17	$N04^0 54.642'$ $E005^0 46.415'$	0.112	0.0120	1.01	104.40	128.04	0.448
18	$N04^0 54.642'$ $E005^0 46.412'$	0.113	0.0121	1.02	105.27	129.10	0.452
19	$N04^0 54.643'$ $E005^0 46.410'$	0.115	0.0123	1.03	107.01	126.22	0.442
20	$N04^0 54.640'$ $E005^0 46.390'$	0.117	0.0125	1.05	108.75	131.24	0.459
Min		0.098	0.0105	0.88	91.35	112.03	0.392
Max		0.117	0.0125	1.05	108.75	131.24	0.459
Mean		$\mathbf{0.106 \pm 0.0055}$	$\mathbf{0.011 \pm 0.00059}$	$\mathbf{0.957 \pm 0.492}$	$\mathbf{98.963 \pm 5.127}$	$\mathbf{121.02 \pm 5.764}$	$\mathbf{0.425 \pm 0.021}$

Table 2: Measured exposure rate and calculated hazard indices in Cloughe Creek community

S/ NO	GPS	BIR μSvh^{-1}	BIR (mRh^{-1})	EDR ($mSvy^{-1}$)	ADR ($nGyh^{-1}$)	AEDE (μSvy^{-1})	ELCR $\times 10^{-3}$
1	$N04^0 51.367'$ $E005^0 41.543'$	0.093	0.0100	0.84	87.00	106.70	0.373

2	N04^{0}51.369′ E005^{0}41.541′	0.095	0.0102	0.86	88.74	108.83	0.381
3	N04^{0}51.370′ E005^{0}41.538′	0.096	0.0103	0.87	89.61	109.90	0.385
4	N04^{0}51.371′ E005^{0}41.536′	0.098	0.0105	0.88	91.35	112.03	0.392
5	N04^{0}51.372′ E005^{0}41.532′	0.091	0.0098	0.82	85.26	104.56	0.366
6	N04^{0}51.373′ E005^{0}41.530′	0.093	0.0100	0.84	87.00	106.70	0.373
7	N04^{0}51.379′ E005^{0}41.531′	0.093	0.0100	0.84	87.00	106.70	0.373
8	N04^{0}51.381′ E005^{0}41.526′	0.095	0.0102	0.86	88.74	108.83	0.381
9	N04^{0}51.389′ E005^{0}41.524′	0.091	0.0098	0.82	85.26	104.56	0.366
10	N04^{0}51.394′ E005^{0}41.526′	0.092	0.0099	0.83	86.13	105.63	0.370
11	N04^{0}51.397′ E005^{0}41.527′	0.089	0.0095	0.80	82.65	101.36	0.356
12	N04^{0}51.400′ E005^{0}41.529′	0.091	0.0098	0.82	85.26	104.56	0.366
13	N04^{0}51.402′ E005^{0}41.532′	0.089	0.0095	0.80	82.65	101.36	0.355
14	N04^{0}51.403′ E005^{0}41.535′	0.093	0.0100	0.84	87.00	106.70	0.373
15	N04^{0}51.403′ E005^{0}41.538′	0.092	0.0099	0.83	86.13	105.63	0.370
16	N04^{0}51.405′ E005^{0}41.540′	0.091	0.0098	0.82	85.26	104.56	0.366
17	N04^{0}51.410′ E005^{0}41.542′	0.092	0.0099	0.83	86.13	105.63	0.370
18	N04^{0}51.414′ E005^{0}41.542′	0.094	0.0101	0.85	87.87	107.76	0.377
19	N04^{0}51.416′ E005^{0}41.543′	0.096	0.0103	0.87	89.61	109.90	0.385
20	N04^{0}51.420′ E005^{0}41.543′	0.090	0.0096	0.81	83.52	104.43	0.366
Min		0.089	0.0095	0.80	82.65	101.36	0.355
Max		0.098	0.0105	0.88	91.35	112.03	0.392
	Mean		$\mathbf{0.010 \pm 0.00026}$	$\mathbf{0.837 \pm 0.023}$	$\mathbf{86.61 \pm 2.301}$	$\mathbf{106.32 \pm 2.715}$	$\mathbf{0.372 \pm 0.0094}$

Table 3: Measured exposure rate and calculated hazard indices in Ofoni community

S/ NO	**GPS**	**BIR µSvh^{-1}**	**BIR (mRh^{-1})**	**EDR (mSvy^{-1})**	**ADR (nGyh^{-1})**	**AEDE (µSvy^{-1})**	**ELCR ×10^{-3}**
1	N05^{0}04.522′ E005^{0}56.746′	0.100	0.0107	0.90	93.09	114.17	0.40
2	N05^{0}04.526′ E005^{0}56.744′	0.100	0.0107	0.90	93.09	114.17	0.40
3	N05^{0}04.530′ E005^{0}56.743′	0.095	0.0102	0.86	88.74	108.83	0.38
4	N05^{0}04.534′ E005^{0}56.743′	0.090	0.0096	0.81	83.52	102.43	0.36
5	N05^{0}04.537′ E005^{0}56.741′	0.089	0.0095	0.80	82.65	101.36	0.35
6	N05^{0}04.539′	0.099	0.0106	0.89	92.22	113.10	0.40

	$E005^{0}56.740'$						
7	$N05^{0}04.545'$ $E005^{0}56.741'$	0.102	0.0109	0.92	94.83	116.30	0.41
8	$N05^{0}04.548'$ $E005^{0}56.742'$	0.106	0.0114	0.96	99.18	121.63	0.43
9	$N05^{0}04.551'$ $E005^{0}56.741'$	0.105	0.0113	0.95	98.31	120.57	0.42
10	$N05^{0}04.553'$ $E005^{0}56.740'$	0.106	0.0114	0.96	99.18	121.63	0.43
11	$N05^{0}04.555'$ $E005^{0}56.739'$	0.108	0.0116	0.98	100.92	123.77	0.43
12	$N05^{0}04.558'$ $E005^{0}56.739'$	0.104	0.0111	0.93	96.57	118.43	0.41
13	$N05^{0}04.564'$ $E005^{0}56.737'$	0.105	0.0113	0.95	98.31	120.57	0.42
14	$N05^{0}04.568'$ $E005^{0}56.737'$	0.103	0.0110	0.93	95.70	117.37	0.41
15	$N05^{0}04.573'$ $E005^{0}56.735'$	0.107	0.0115	0.97	100.05	122.70	0.43
16	$N05^{0}04.576'$ $E005^{0}56.733'$	0.101	0.0108	0.91	93.96	115.23	0.40
17	$N05^{0}04.579'$ $E005^{0}56.729'$	0.090	0.0096	0.81	83.52	102.43	0.36
18	$N05^{0}04.581'$ $E005^{0}56.728'$	0.088	0.0094	0.79	81.78	100.29	0.35
19	$N05^{0}04.583'$ $E005^{0}56.724'$	0.082	0.0088	0.74	76.56	93.89	0.33
20	$N05^{0}04.586'$ $E005^{0}56.723'$	0.082	0.0088	0.74	76.56	93.89	0.33
Min		0.082	0.0088	0.74	76.56	93.89	0.33
Max		0.108	0.0116	0.98	100.92	123.77	0.43
	Mean		$\mathbf{0.011 \pm 0.0009}$	$\mathbf{0.885 \pm 0.0024}$	$\mathbf{91.437 \pm 7.923}$	$\mathbf{112.138 \pm 9.718}$	$\mathbf{0.393 \pm 0.034}$

Table 4: Measured exposure rate and calculated hazard indices in Agbere community

S/ NO	**GPS**	**BIR** μSvh^{-1}	**BIR** (mRh^{-1})	**EDR** $(mSvy^{-1})$	**ADR** $(nGyh^{-1})$	**AEDE** (μSvy^{-1})	**ELCR** $\times 10^{-3}$
1	$N05^{0}13.663'$ $E005^{0}24.302'$	0.236	0.0253	2.13	220.11	269.94	0.94
2	$N05^{0}13.656'$ $E005^{0}24.800'$	0.097	0.0104	0.87	90.48	110.96	0.39
3	$N05^{0}13.654'$ $E005^{0}24.294'$	0.098	0.0105	0.88	91.35	112.03	0.39
4	$N05^{0}13.656'$ $E005^{0}24.288'$	0.105	0.0113	0.95	98.31	120.57	0.42
5	$N05^{0}13.659'$ $E005^{0}24.284'$	0.105	0.0113	0.95	98.31	120.57	0.42
6	$N05^{0}13.662'$ $E005^{0}24.282'$	0.104	0.0111	0.93	96.57	118.43	0.41
7	$N05^{0}13.665'$ $E005^{0}24.281'$	0.107	0.0115	0.97	100.05	122.70	0.43
8	$N05^{0}13.668'$ $E005^{0}24.278'$	0.108	0.0116	0.98	100.92	123.77	0.43
9	$N05^{0}13.670'$ $E005^{0}24.275'$	0.103	0.0110	0.93	95.70	117.37	0.41
10	$N05^{0}13.673'$ $E005^{0}24.270'$	0.109	0.0117	0.98	101.79	124.84	0.44

11	$N05^0 13.674'$ $E005^0 24.268'$	0.112	0.0120	1.01	104.40	128.04	0.45
12	$N05^0 13.678'$ $E005^0 24.265'$	0.109	0.0117	0.98	101.79	124.84	0.44
13	$N05^0 13.651'$ $E005^0 24.287'$	0.112	0.0120	1.01	104.40	128.04	0.45
14	$N05^0 13.649'$ $E005^0 24.289'$	0.114	0.0122	1.03	106.14	130.17	0.46
15	$N05^0 13.645'$ $E005^0 24.291'$	0.114	0.0122	1.03	106.14	130.17	0.46
16	$N05^0 13.661'$ $E005^0 24.308'$	0.116	0.0124	1.04	107.88	132.30	0.46
17	$N05^0 13.663'$ $E005^0 24.312'$	0.116	0.0124	1.04	107.88	132.30	0.46
18	$N05^0 13.665'$ $E005^0 24.317'$	0.124	0.0133	1.12	115.71	141.91	0.50
19	$N05^0 13.666'$ $E005^0 24.323'$	0.132	0.0141	1.19	122.67	150.44	0.53
20	$N05^0 13.668'$ $E005^0 24.328'$	0.132	0.0141	1.19	122.67	150.44	0.53
Min		0.097	0.0104	0.87	90.48	110.96	0.39
Max		0.236	0.0253	2.13	220.11	269.94	0.94
	Mean		$\mathbf{0.013 \pm 0.0032}$	$\mathbf{1.061 \pm 0.2659}$	$\mathbf{109.66 \pm 27.4153}$	$\mathbf{134.49 \pm 33.6214}$	$\mathbf{0.471 \pm 0.117}$

Table 5: Measured exposure rate and calculated hazard indices in Tunu community

S/ NO	**GPS**	**BIR μSvh^{-1}**	**BIR (mRh^{-1})**	**EDR $(mSvy^{-1})$**	**ADR $(nGyh^{-1})$**	**AEDE (μSvy^{-1})**	**ELCR $\times 10^{-3}$**
1	$N04^0 53.054'$ $E005^0 36.920'$	0.085	0.0091	0.77	79.17	97.09	0.34
2	$N04^0 53.057'$ $E005^0 36.916'$	0.084	0.0090	0.76	78.30	96.03	0.34
3	$N04^0 53.059'$ $E005^0 36.913'$	0.080	0.0086	0.72	74.82	91.76	0.32
4	$N04^0 53.061'$ $E005^0 36.912'$	0.078	0.0084	0.71	73.08	89.63	0.31
5	$N04^0 53.063'$ $E005^0 36.908'$	0.081	0.0087	0.73	75.69	92.83	0.32
6	$N04^0 53.060'$ $E005^0 36.910'$	0.081	0.0087	0.73	75.69	92.83	0.32
7	$N04^0 53.071'$ $E005^0 36.912'$	0.080	0.0086	0.72	74.82	91.76	0.32
8	$N04^0 53.075'$ $E005^0 36.915'$	0.079	0.0085	0.71	73.95	90.69	0.32
9	$N04^0 53.094'$ $E005^0 36.886'$	0.074	0.0079	0.66	68.73	84.29	0.30
10	$N04^0 53.098'$ $E005^0 36.878'$	0.074	0.0079	0.66	68.73	84.29	0.30
11	$N04^0 53.099'$ $E005^0 36.874'$	0.073	0.0078	0.66	67.86	83.22	0.29
12	$N04^0 53.100'$ $E005^0 36.871'$	0.073	0.0078	0.66	67.86	83.22	0.29
13	$N04^0 53.102'$ $E005^0 36.868'$	0.071	0.0076	0.64	66.12	81.09	0.28
14	$N04^0 53.106'$ $E005^0 36.864'$	0.071	0.0076	0.64	66.12	81.09	0.28
15	$N04^0 53.107'$	0.072	0.0077	0.65	66.99	82.16	0.29

	$E005^0 36.861'$						
16	$N04^0 53.108'$ $E005^0 36.857'$	0.073	0.0078	0.66	67.86	83.22	0.29
17	$N04^0 53.111'$ $E005^0 36.854'$	0.073	0.0078	0.66	67.86	83.22	0.29
18	$N04^0 53.112'$ $E005^0 36.851'$	0.077	0.0083	0.70	72.21	88.56	0.31
19	$N04^0 53.112'$ $E005^0 36.849'$	0.075	0.0080	0.67	69.60	85.36	0.30
20	$N04^0 53.115'$ $E005^0 36.849'$	0.077	0.0083	0.70	72.21	88.56	0.31
Min		0.071	0.0076	0.64	66.12	81.09	0.28
Max		0.085	0.0091	0.77	79.17	97.09	0.34
	Mean		$\mathbf{0.0082 \pm 0.00047}$	$\mathbf{0.690 \pm 0.0395}$	$\mathbf{71.38 \pm 4.1144}$	$\mathbf{87.55 \pm 5.0467}$	$\mathbf{0.306 \pm 0.0179}$

Table 6: The Calculated Mean Background Ionizing Radiation (BIR) Levels of the Selected Communities in Bayelsa West Senatorial District, Bayelsa State

S /NO	Location	BIR (mRh^{-1})	EDR $(mSvy^{-1})$	ADR $(nGyh^{-1})$	AEDE (μSvy^{-1})	ELCR $\times 10^{-3}$
1	Opukushi	0.011 ± 0.00059	0.957 ± 0.492	98.963 ± 5.127	121.02 ± 5.764	0.425 ± 0.021
2	Cloughe Creek	0.010 ± 0.00026	0.837 ± 0.023	86.61 ± 2.301	106.32 ± 2.715	0.372 ± 0.0094
3	Ofoni	0.011 ± 0.0009	0.885 ± 0.0024	91.437 ± 7.923	112.138 ± 9.718	0.393 ± 0.034
4	Agbere	0.013 ± 0.0032	1.061 ± 0.2659	109.66 ± 27.4153	134.49 ± 33.6214	0.471 ± 0.117
5	Tunu	0.0082 ± 0.00047	0.690 ± 0.0395	71.38 ± 4.1144	87.55 ± 5.0467	0.306 ± 0.0179
	Mean	$\mathbf{0.0106 \pm 0.0017}$	$\mathbf{0.886 \pm 0.138}$	$\mathbf{91.610 \pm 14.267}$	$\mathbf{112.304 \pm 17.441}$	$\mathbf{0.393 \pm 0.0615}$
	UNSCEAR, 2002	0.013	1	84	70	0.29

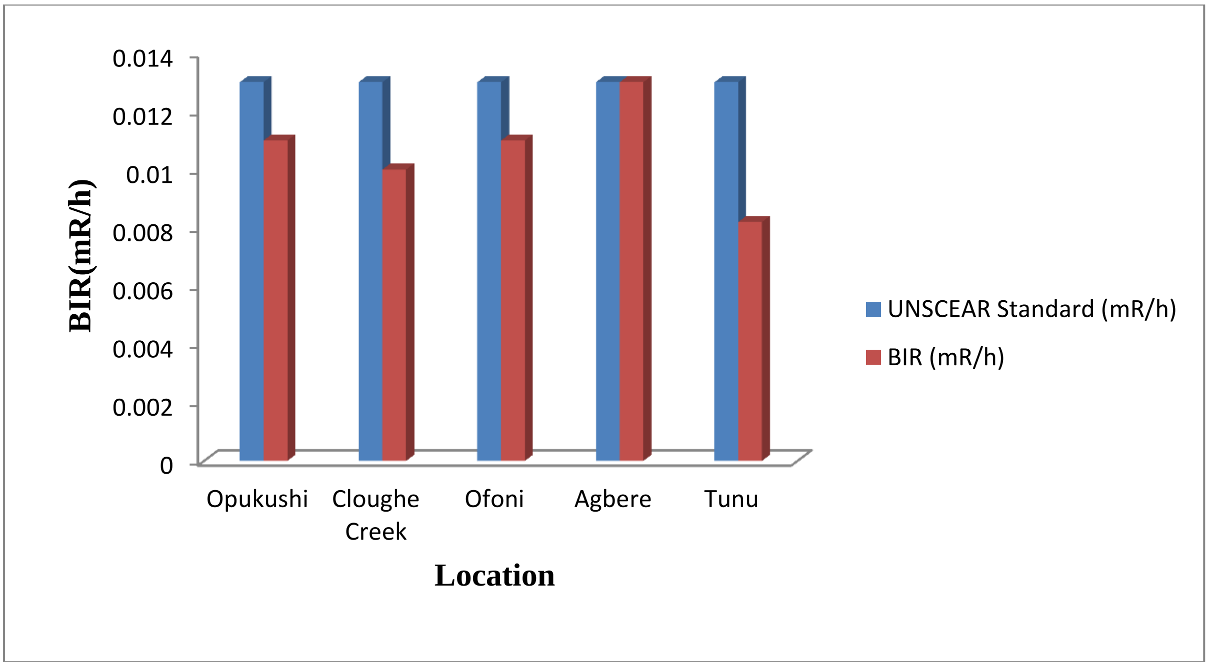

Figure 3: Comparison of BIR level measurement in the study area versus UNSCEAR (2002) standard

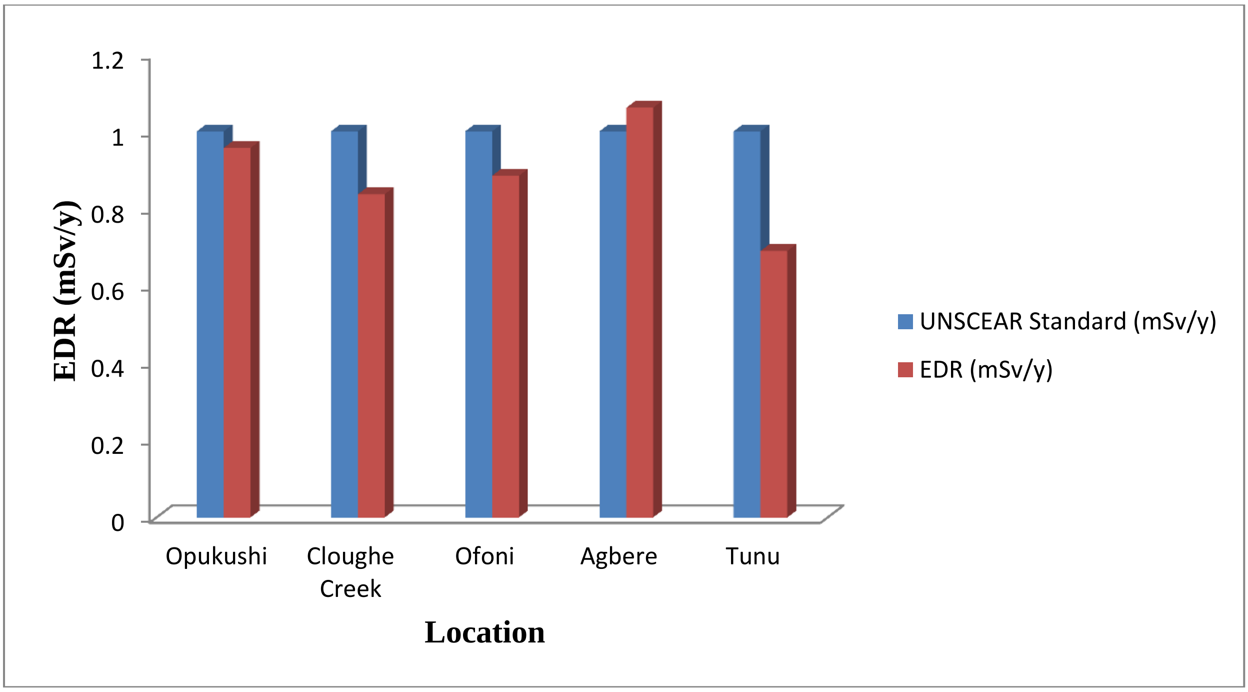

Figure 4: Comparison of Equivalent Dose Rate (EDR) in the study area versus UNSCEAR (2002) standard

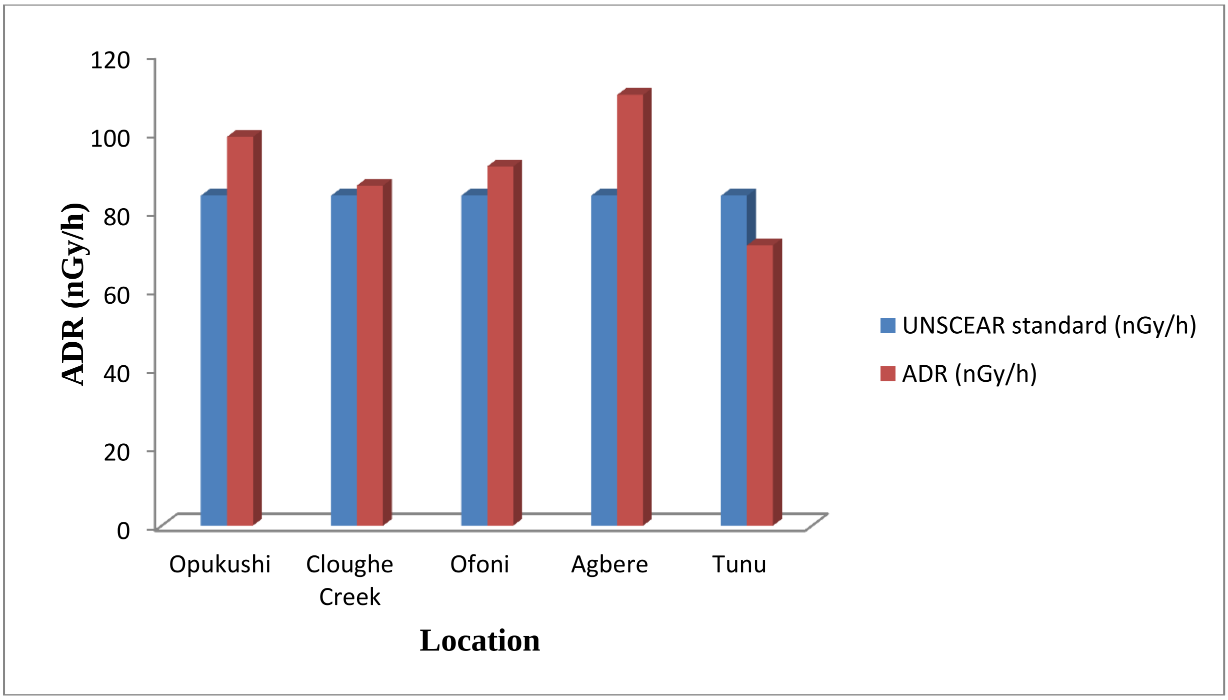

Figure 5: Comparison of Absorbed Dose Rate (ADR) in the study area versus UNSCEAR (2002) standard

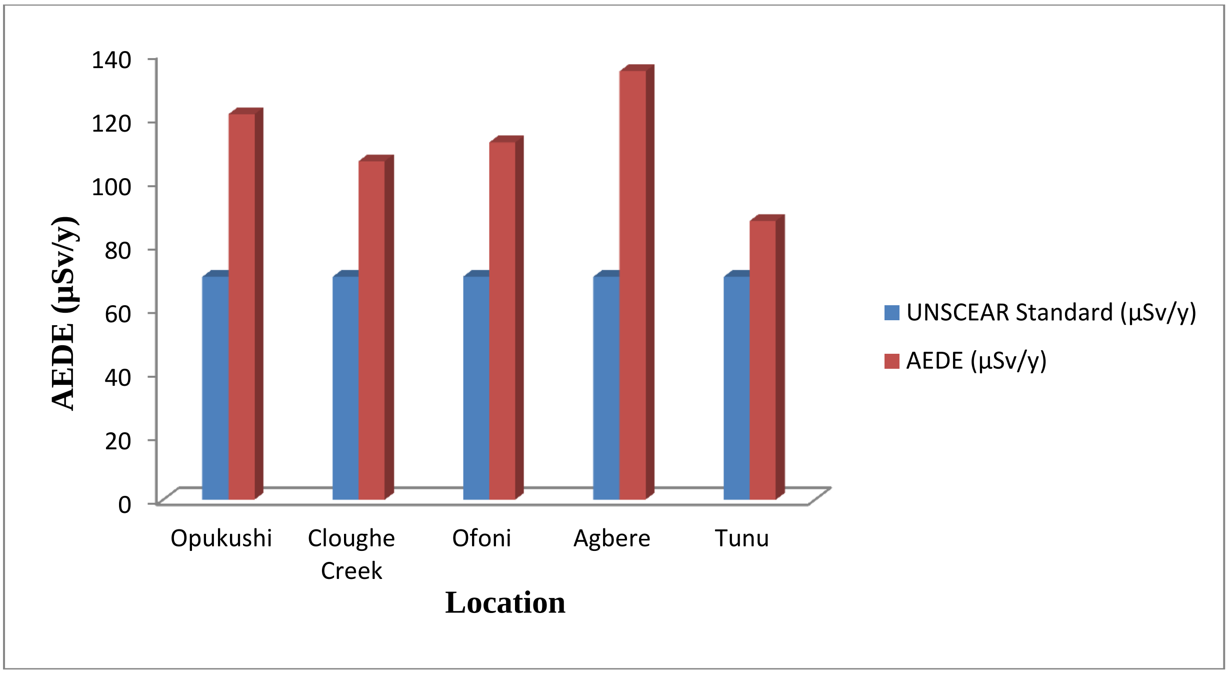

Figure 6: Comparison of Annual Equivalent Dose Rate (AEDE) in the study area versus UNSCEAR (2002) standard

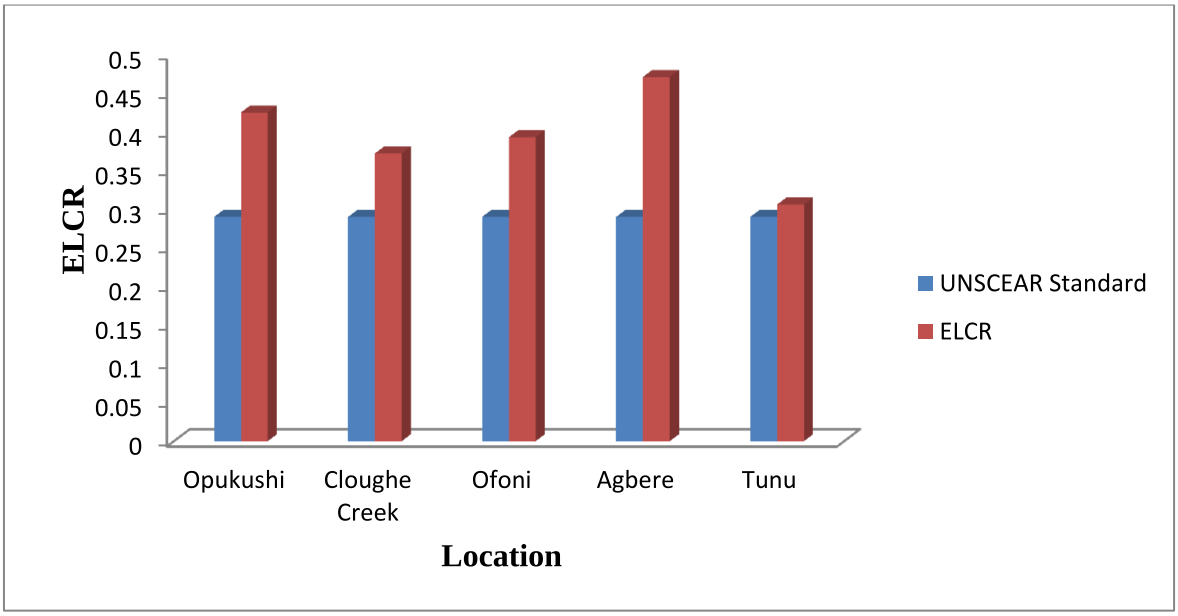

Figure 7: Comparison of Excess Lifetime Cancer Risk (ELCR) in the study area versus UNSCEAR (2002) standard

IV. Discussion

Background Ionizing Radiation (BIR) Exposure Levels:

The calculated mean of Background Ionizing Radiation (BIR) exposure level in the studied areas as presented in Table 4.6 varied from 0.0082 ± 0.00026 mRh^{-1} (Tunu) to 0.013 ± 0.0032 mRh^{-1} (Agbere) with an overall mean of 0.0106 ± 0.0017 mRh^{-1}. The result obtained from the study are below and consistent with the World recommended safety limit of 0.013 mRh^{-1} (UNSCEAR, 2000). The obtained results are below the reported range values of Anekwe et al., (2023), Audu et al., (2019) and Avwiri et al., (2014). The absence of sediments containing radionuclides in the area caused the obtained values to be lower.

Equivalent dose rate (EDR):

The results of the calculated whole body mea equivalent dose rate for the communities within the study area are presented in the table 6 above. The estimated Equivalent Dose Rate (EDR) ranged from $0.690 \pm 0.0395\ \mathrm{mSvy^{-1}}$ (Tunu) to $1.061 \pm 0.023\ \mathrm{mSvy^{-1}}$ (Agbere), the reported overall mean value of the study area is $0.886 \pm 0.138\ \mathrm{mSvy^{-1}}$, which is below the world permissible limit of $1\ \mathrm{mSvy^{-1}}$ (UNSCEAR, 2000). The reported values of the equivalent dose rate are lower than Anekwe et al., (2023) and Avwiri et al., (2014). Figure 4 shows the comparison of Equivalent Dose Rate (EDR) in the study area versus UNSCEAR (2002) standard.

Absorbed Dose Rate (ADR):

The estimated mean Absorbed Dose Rate (ADR) of the studied areas ranged from $71.38 \pm 4.1144\ \mathrm{nGyh^{-1}}$ (Tunu) to $109.66 \pm 27.4153\ \mathrm{nGyh^{-1}}$ (Agbere). The reported overall mean of the study area was valued at $91.610 \pm 14.267\ \mathrm{nGyh^{-1}}$, which is observed to be higher than the recommended value of $84.0\ \mathrm{nGyh^{-1}}$ (UNSCEAR, 2000). The reported values of the absorbed dose rate in this study when compared with Audu et al. (2019), Ononugbo et al. (2017) and Anekwe et al., (2023) were less than the reported values in their study. The longer-term drilling chips (TENORM) accumulation brought on by extended oil and gas activities in these environments may be the cause of the higher absorbed dose rates attained in oil and gas fields and host towns Esendu, (2021) mentions it. Figure 5 shows the comparison of Absorbed Dose Rate (ADR) in the study area versus UNSCEAR (2002) standard.

Annual Equivalent Dose Equivalent (AEDE):

The estimated value of Annual Effective Dose Equivalent (AEDE) ranged from $87.55 \pm 5.0467\ \mathrm{\mu Svy^{-1}}$ (Tunu) to $134.49 \pm 33.6214\ \mathrm{\mu Svy^{-1}}$ (Agbere). The estimated overall mean result from the study area is valued at $112.304 \pm 17.441\ \mathrm{\mu Svy^{-1}}$, which is higher than the recommended world average of $70\ \mathrm{\mu Svy^{-1}}$ (ICRP, 2007) but lower than results obtained in Ononugbo et al., (2017) study. This suggests that although the constant exploitation and exploration of oil and gas has radiologically contaminated the research area, there is no acute radioactive health danger there. Figure 6 shows the comparison of Annual Equivalent Dose Rate (AEDE) in the study area versus UNSCEAR (2002) standard.

Excess Lifetime Cancer Risk (ELCR):

The computed mean value of Excess Lifetime Cancer Risk (ELCR) ranged from $0.306 \times 10^{-3} \pm 0.0179$ (Tunu) to $0.471 \times 10^{-3} \pm 0.117$ (Agbere). The computed mean values of the study area was valued at $0.393 \times 10^{-3} \pm 0.0615$, which is observed to had exceeded the ICRP, (2007) standard limit of 0.29×10^{-3} but lower when compared with Ononugbo et al. (2017), Audu et al. (2019), and Anekwe et al. (2023). Figure 7 shows the comparison of Excess Lifetime Cancer Risk (ELCR) in the study area versus UNSCEAR (2002) standard. These high Excess Lifetime Cancer Risk values suggest that residents who intend to live their entire lives in the oil and gas-producing communities run the danger of developing cancer. Our findings point to increased lifetime cancer risk and absorbed dose rate in the study area. To the population of the oil-producing villages in Bayelsa West Senatorial District, Bayelsa State, these values might not pose any immediate health risks. However, there may be a chance that the public will face long-term health problems.

V. CONCLUSION

The study of the terrestrial Background Ionizing Radiation levels of Oil producing communities in Bayelsa West Senatorial District, Bayelsa State, Nigeria have been carried out in order to estimate the radiological health risk parameters. The following conclusions were obtained from the present study.

1. The Background Ionizing Radiation (BIR) and Equivalent Dose Rate (EDR) where below their standard limits
2. The Absorbed Dose Rate (ADR), Annual Effective Dose Equivalent (AEDE) and Excess Lifetime Cancer Risk (ELCR) were above their standard limits.

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