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Comparative Assessment of Environmental Gamma Radiation and Radiological Risk Indices in Selected Ibeno River Communities, Akwa Ibom State, Nigeria

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ABSTRACT
Background ionizing radiation (BIR) constitutes a major source of public exposure to natural radiation and may pose potential health risks when elevated above global reference levels. This study assessed outdoor gamma radiation levels and associated radiological health risks in selected communities of Ibeno Local Government Area, Akwa Ibom State, Nigeria. In situ measurements of exposure rates were conducted across Ikot Ekwong, Obufa Eyet, Isoh Idem, Ima Eyet Ikot, Mkpanak, and Odoro Okoko using a calibrated portable radiation survey meter at 1 m above ground level. Absorbed dose rate (ADR), annual effective dose equivalent (AEDE), and excess lifetime cancer risk (ELCR) were estimated using standard radiological conversion factors recommended by the International Commission on Radiological Protection (ICRP). The mean exposure rates ranged from 0.045 ± 0.01 to 0.063 ± 0.01 μSv h^{-1}, corresponding to absorbed dose rates of 45 ± 11 to 63 ± 8 nGy h^{-1}. The estimated AEDE varied between 0.0552 ± 0.01 and 0.0773 ± 0.01 mSv y^{-1}, while ELCR values ranged from 0.193×10^{-3} to 0.27×10^{-3}. All measured radiological parameters were below the ICRP recommended limits for public exposure, indicating no immediate radiological health concern. However, continuous monitoring is recommended due to ongoing anthropogenic activities in the area.

Keywords: Background ionizing radiation, external gamma radiation, radiological risk indices, health hazard.

1. INTRODUCTION

Natural radioactivity is a worldwide occurrence that is mainly due to the primordial radionuclides which have been present since the earth was being formed. These radionuclides are ubiquitous in rocks, soils, water bodies, and the atmosphere with uranium (238U), thorium (232Th) and potassium (40K) being the most common and playing a significant role in background ionising radiation exposures of human populations across the globe. Although the natural background radiation is usually low and spatially varied, human activities especially crude oil and gas exploration, production and processing can considerably change its distribution and intensity.

Naturally Occurring Radioactive Materials (NORMs) that are entrenched in the underground geological formations are often mobilised and brought to the surface during drilling, extraction and production operations in oil- and gas-producing areas. These radionuclides, such as decay series of uranium and thorium, in particular, radium isotopes (226Ra and 228Ra), can be washed to the surface by the generated water, drilling muds, scale deposits, and sludge (Kpeglo, 2015). When discharged into the environment, these materials can be deposited in soils, sediments, surface water, and biota, which leads to the enhancement of ambient radiation and has long-term environmental and population health implications.

Various studies have been conducted globally and found high levels of radiations in oil producing areas. Middle East, Eastern European, South American, and some Asian investigations have demonstrated that petroleum activities may boost the level of background gamma radiation and augment the level of NORMs in the adjacent ecosystems (Ali et al., 2019; UNSCEAR, 2021). Oilfield brines and polluted sediments have been found to be major causes of localised radiological hotspots especially along river channels and wetlands receiving produced water discharges in the United States and parts of Europe (Johnson, 2017).

The major sources of environmental background radiation are still 40K, 238U, 232Th, and their offspring. These radionuclides are also released as alpha, beta, and gamma radiation, and when these radionuclides are deposited in the environment, especially in the soil, plants, air, and water, they can cause chronic exposure to low doses. Excessive exposure to such radiation even at low dose rates has been linked to higher risks of stochastic health effects such as cancer (Wiescher, 2025). The radiological hazard is further increased in areas where the contaminated soils and sediments are used as secondary sources of radiations in terms of inhalation, ingestion, and external irradiation routes.

Along with natural sources, industrial and technological processes such as oil and gas production, mining, medical and research-oriented practise are also sources of the increase in environmental radioactivity. This group of sources is known as Technologically Enhanced Naturally Occurring Radioactive Materials (TENORM) (Johnson, 2017). TENORM occurs in the petroleum sector when natural radionuclides are highly concentrated than they were originally because of the chemical and physical processes involved during extraction and processing. The mismanagement of the TENORM-contaminated wastes is a severe radiological and environmental threat, especially in the developing world where there is limited enforcement of regulations.

Crude oil radionuclides found in the oils reservoirs can diffuse to the surface and groundwater systems in oil spills, pipeline leakages, and unlawful bunkering of oil. Research in the Niger Delta of Nigeria has continually recorded high levels of background radiation in the oil producing communities as opposed to other areas not producing oil (Avwiri and Tchokossa, 2006). Ingestion of radium has been associated with bone sarcomas and nasal tumours whereas inhalation of radon, a decay product of radium, has been known as a well-established risk factor of lung cancer. It has also been reported that chronic exposure to uranium causes renal toxicity and lung cancer and lymphatic cancers.

In addition to radiological pollution, crude oil spillage interferes with physicochemical characteristics and biodiversity of microbes in the soil, distorting the natural balance of ecosystems. These alterations can affect the mobility, bioavailability and redistribution of radionuclides, which alters radiation exposure routes. Radiological risks in these settings are highly influenced by the degree, frequency, and geographical dispersion of petroleum pollution. In Nigeria, the rising cases of non-communicable diseases in oil producing communities such as Ibeno in Akwa Ibom State have raised the level of concern with regards to the long-term exposure to the environment and the overall health of the population (Vaiserman, 2018).

However, in spite of the increasing literature on the environment of oil-producing areas worldwide, site-specific radiometric information of most communities in the Akwa Ibom State is still limited. Moreover, little has been done concerning comparative evaluation of ambient radiation levels in various oil-affected sites in the same ecological area. This kind of data is essential in the assessment of environmental risks, in regulatory decision making and mitigation strategies. The purpose of this study therefore is to explore the level of environmental background ionising radiations prevalent in selected communities along the Ibeno River of Akwa Ibom State, Nigeria. The objectives of this study are centered on the comprehensive assessment of environmental radiological conditions in oil-impacted areas. Specifically, the study seeks to conduct in-situ measurements of background gamma radiation levels using portable radiation monitoring instruments. Furthermore, it aims to determine key radiological risk parameters, including absorbed dose rates (ADR), annual effective dose equivalents (AEDE), and excess lifetime cancer risks (ELCR) associated with environmental exposure. In addition, the study intends to evaluate the potential radiological health implications arising from prolonged exposure to naturally occurring radioactive materials (NORMs) in oil-polluted environments. It is hoped that the results of this study will provide important baseline radiometric data on the Niger Delta area, assist in the environmental radiation mapping activities, and offer scientific data to inform the policy of public health and protection of radiation in the oil-producing communities.

2. MATERIALS AND METHODS

3.1 Study Area

The research was carried out in certain communities that were resettled along the Ibeno River in the Akwa Ibom State which is in Southern Nigeria. Akwa Ibom State is located in the Niger Delta Region that is among the most prominent crude oil-producing regions in Nigeria. In Ibeno region, especially, there has been a large scale exploration and production of oil and gas and the region has been the centre of petroleum related activities over the past few decades. This has led to frequent environmental upheavals in the region such as crude oil spills, pipeline leakages, gas flaring, and illegal bunkering, particularly in the past five years.

The particular communities to be used in this study are Ikot Ekwong, O bufa Eyet, Isoh Idem, Ima Eyet Ikot, Mkpanak and Odoro Okoko communities. These communities are located near the Ibeno River and the oil infrastructure and were selected due to known records of hydrocarbon contamination and ongoing anthropogenic processes that could affect the background radiation level. To facilitate identification and spatial analysis, the chosen sampling points were labelled with a shortened abbreviations with each site being georeferenced through a Global Positioning System (GPS).

Geographically, the study area lies within the coastal lowland plains of the Niger Delta and is characterized by mangrove swamps, creeks, and estuarine environments. The region falls within the humid tropical climatic zone, marked by high annual rainfall and consistently high relative humidity. Average temperatures range between 21 °C and 26 °C, creating conditions that promote intense weathering and leaching of soils. Such environmental conditions can influence the mobilization and redistribution of naturally occurring radionuclides in soil and sediment matrices.

A comparative cross-sectional research design was adopted for this study. This approach enabled the assessment and comparison of ambient radiation levels across multiple crude oil–impacted sites within the study area at a single time point. The design was considered appropriate for identifying spatial variations in environmental radiation exposure and evaluating the potential influence of prolonged petroleum-related activities on natural background radiation levels. The selection of the study sites was therefore based on their varying degrees of exposure to oil pollution, proximity to oil facilities, and intensity of anthropogenic disturbances, which collectively may contribute to elevated radiological risk in the environment.

3.2 Materials and Equipment

The materials and equipment used for the radiometric survey included a Radalert-100 Nuclear Radiation Monitor for in-situ measurement of background ionizing radiation, a Global Positioning System (GPS) receiver for recording the geographical coordinates of each measurement point, and field data sheets for systematic documentation of observations. The Radalert-100 is a portable Geiger–Müller (GM) based detector capable of measuring alpha, beta, gamma, and X-ray radiation, with exposure rate readings displayed in millirSievert per hour ($\mu Sv \cdot h^{-1}$), making it suitable for environmental radiation monitoring.

3.3 Field Measurement Procedure

In-situ radiation measurements were conducted at selected sampling locations within the study area. At each location, the radiation monitor was held at approximately 1 m above ground level, corresponding to the average height of human gonads, to realistically estimate human exposure. Measurements were taken under stable weather conditions to minimize atmospheric influences on radiation levels. Multiple readings were recorded at each point, and the mean exposure rate was computed to reduce random fluctuations and improve data reliability. The corresponding geographic coordinates of each point were recorded using the GPS device.

3.4 Health Risk Parameters

A. Mean Exposure Rate

The mean exposure rate (ER), expressed in microsievert per hour ($\mu Sv \cdot h^{-1}$), represents the average rate at which ionizing radiation delivers effective dose to air at a given measurement location. This quantity provides a direct indication of ambient background radiation levels and reflects the potential external radiation exposure to individuals within the environment. The measured exposure rate constitutes the primary radiometric parameter from which absorbed dose rate and other radiological risk indices were subsequently derived.

B. Absorbed Dose Rate

The absorbed dose rate (ADR) describes the amount of radiation energy absorbed per unit mass of air and is expressed in nanogray per hour ($nGy \cdot h^{-1}$). For environmental gamma radiation, the effective dose and absorbed dose in air are approximately equivalent, since the radiation weighting factor for gamma radiation is unity (Q = 1). Following UNSCEAR (2000) and consistent with earlier studies (Ali et al., 2019), the absorbed dose rate was obtained by converting the measured exposure rate in $\mu Sv \cdot h^{-1}$ using the relationship:

$$D = ER \times 1000$$

Where

D is the absorbed dose rate in $nGy \cdot h^{-1}$, and *ER* is the exposure rate in $\mu R \cdot h^{-1}$. This conversion is based on the approximation that, for gamma radiation in air,

$$1\,\mu Sv/h \approx 1\,\mu Gy/h = 1000\,nGy/h$$

which allows direct comparison of measured dose rates with internationally recommended background radiation limits.

C. Annual Effective Dose Equivalent

The Annual Effective Dose Equivalent (AEDE) represents the cumulative radiation dose received by an individual over one year and incorporates exposure duration, radiation type, and biological sensitivity of human tissues. It provides a more realistic estimate of potential radiological health effects. The AEDE, expressed in millisievert per year ($mSv \cdot y^{-1}$), was calculated in accordance with the recommendations of the International Commission on Radiological Protection (ICRP, 2007) using the expression:

$$AEDE = D \times T \times Q$$

For outdoor exposure conditions, this relationship was expanded as:

$$AEDE = D \times 8760 \times 0.2 \times 0.7 \times 10^{-6}$$

where:
D = absorbed dose rate ($nGy \cdot h^{-1}$),
T = time ($8760\ h \cdot y^{-1}$),
Q = quality factor for gamma radiation ($Q = 1$),
0.2 = outdoor occupancy factor (assumes 20% of time spent outdoors), and
0.7 = dose conversion coefficient from absorbed dose in air to effective dose ($Sv \cdot Gy^{-1}$) for adults.

D. Excess Lifetime Cancer Risk
The Excess Lifetime Cancer Risk (ELCR) estimates the probability of developing cancer over a lifetime due to exposure to ionizing radiation. It is a probabilistic indicator widely used in radiological risk assessment. The ELCR was evaluated using the following expression:

$$ELCR = AEDE \times DL \times RF$$

where:
$AEDE$ = annual effective dose equivalent ($\mu Sv \cdot y^{-1}$),
DL = average duration of life (70 years), and
RF = fatal cancer risk factor per Sievert ($0.05\ Sv^{-1}$, corresponding to 5% per sievert for the public, as recommended by ICRP).
The ELCR values were expressed in units of $\times 10^{-3}$ to facilitate comparison with similar environmental radiation.

3. PRESENTATION OF RESULTS

The results of the study are presented in Tables 1 to 7. While the Tables from 1 to 6 show the exposure rate, ADR, AEDE, and ELCR for the sampled communities in the location, Table & shows the average values obtained for the aforementioned health risk parameters. The continuous line distribution of exposures rates are shown using a contour map in figure 1.

Table 1. Exposure rate results and associated health risks from Ikot Ekwong Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
IE1	8.0046	4.5669	0.05	50	0.0613	0.215
IE2	8.00478	4.565997	0.04	40	0.0491	0.172
IE3	8.004373	4.564601	0.03	30	0.0368	0.129
IE4	8.004509	4.568519	0.05	50	0.0613	0.215
IE5	8.004825	4.569374	0.06	60	0.0736	0.258
IE 6	8.002837	4.564556	0.06	60	0.0736	0.258
IE7	8.001482	4.5637	0.05	50	0.0613	0.215
IE8	8.003198	4.566267	0.04	40	0.0491	0.172
IE9	8.006045	4.57005	0.05	50	0.0613	0.215
IE10	8.004689	4.57059	0.05	50	0.0613	0.215
Mean			0.048 ± 0.01	48 ± 9.00	0.0589 ± 0.01	0.206 ± 0.04

Table 2. Exposure rate results and associated health risks from Obufa Eyet Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
OE1	8.0028	4.5624	0.06	60	0.0736	0.258
OE2	8.004147	4.562754	0.06	60	0.0736	0.258
OE3	8.003108	4.561088	0.06	60	0.0736	0.258
OE4	8.001617	4.560908	0.07	70	0.0858	0.3
OE5	8.001527	4.559557	0.08	80	0.0981	0.343
OE6	8.003108	4.559196	0.06	60	0.0736	0.258
OE7	8.004283	4.559286	0.05	50	0.0613	0.215
OE8	7.999991	4.559962	0.05	50	0.0613	0.215
OE9	7.998138	4.560052	0.04	40	0.0491	0.172
OE10	7.996986	4.560457	0.04	40	0.0491	0.172
	Mean		0.057 ± 0.01	57 ± 13.00	0.0699 ± 0.02	0.245 ± 0.05

Table 3. Exposure rate results and associated health risks from Isoh Idem Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
II1	8.007967	4.561717	0.07	70	0.0858	0.3
II2	8.006654	4.562259	0.07	70	0.0858	0.3
II3	8.009275	4.561268	0.07	70	0.0858	0.3
II4	8.008371	4.560908	0.06	60	0.0736	0.258
II5	8.007332	4.560773	0.05	50	0.0613	0.215
II6	8.008145	4.559962	0.06	60	0.0736	0.258
II7	8.005299	4.562754	0.04	40	0.0491	0.172
II8	8.007151	4.563159	0.04	40	0.0491	0.172
II9	8.008733	4.56343	0.06	60	0.0736	0.258
II10	8.006383	4.559467	0.04	40	0.0491	0.172
	Mean		0.056 ± 0.01	56 ± 13.00	0.0687 ± 0.016	0.24 ± 0.05

Table 4. Exposure rate results and associated health risks from Ima Eyet Ikot Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
IEI1	8.01145	4.560583	0.07	70	0.0858	0.3
IEI2	8.012573	4.560502	0.07	70	0.0858	0.3
IEI3	8.010337	4.559602	0.07	70	0.0858	0.3
IEI4	8.011895	4.559489	0.06	60	0.0736	0.258
IEI5	8.012957	4.558363	0.05	50	0.0613	0.215
IEI6	8.012844	4.557327	0.05	50	0.0613	0.215
IEI7	8.014154	4.560457	0.07	70	0.0858	0.3
IEI8	8.012799	4.556066	0.06	60	0.0736	0.258
IEI9	8.012867	4.55485	0.06	60	0.0736	0.258
IEI10	8.016684	4.560615	0.07	70	0.0858	0.3
	Mean		0.063 ± 0.01	63 ± 8.00	0.0773 ± 0.01	0.27 ± 0.04

Table 5. BIR results and associated health risks from Mkpanak Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
MP1	8.002367	4.554283	0.05	50	0.0613	0.215
MP2	8.002464	4.55717	0.05	50	0.0613	0.215
MP3	8.001459	4.55708	0.03	30	0.0368	0.129
MP4	8.001956	4.555549	0.04	40	0.0491	0.172
MP5	8.002114	4.553421	0.04	40	0.0491	0.172
MP6	8.002046	4.551777	0.03	30	0.0368	0.129
MP7	8.000985	4.552137	0.06	60	0.0736	0.258
MP8	7.999697	4.552925	0.07	70	0.0858	0.3
MP9	8.002295	4.550448	0.05	50	0.0613	0.215
MP10	8.00234	4.548894	0.05	50	0.0613	0.215
	Mean		0.047 ± 0.01	47 ± 13.00	0.0576 ± 0.02	0.202 ± 0.05

Table 6. BIR results and associated health risks from Odoro Okoko Community

Location	Longitude	Latitude	Exposure rate (μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
OO1	8.021041	4.56168	0.06	60	0.0736	0.258
OO2	8.024557	4.561308	0.05	50	0.0613	0.215
OO3	8.02706	4.561893	0.03	30	0.0368	0.129
OO4	8.028551	4.560778	0.04	40	0.0491	0.172
OO5	8.02983	4.558707	0.06	60	0.0736	0.258
OO6	8.030362	4.557486	0.05	50	0.0613	0.215
OO7	8.029404	4.557167	0.05	50	0.0613	0.215
OO8	8.028072	4.558017	0.04	40	0.0491	0.172
OO9	8.027273	4.559397	0.03	30	0.0368	0.129
OO10	8.026527	4.560671	0.04	40	0.0491	0.172
	Mean		0.045 ± 0.01	45 ± 11.00	0.0552 ± 0.01	0.193 ± 0.05

Table 7. Average BIR results and associated health risks from Ibeno Communities

Location	Latitude	Longitude	Exposure rate μSv/h)	ADR (nGr/h)	AEDE (μSv/y)	ELCR ($x10^{-3}$)
Ikot Ekwong	8.004509	4.568519	0.048 ± 0.01	48 ± 9.00	0.0589 ± 0.01	0.206 ± 0.04
Obufa Eyet	8.001527	4.559557	0.057 ± 0.01	57 ± 13.00	0.0699 ± 0.02	0.245 ± 0.05
Isoh Idem	8.008371	4.560908	0.056 ± 0.01	56 ± 13.00	0.0687 ± 0.016	0.24 ± 0.05
Ima Eyet Ikot	8.012957	4.558363	0.063 ± 0.01	63 ± 8.00	0.0773 ± 0.01	0.27 ± 0.04
Mkpanak	7.999697	4.552925	0.047 ± 0.01	47 ± 13.00	0.0576 ± 0.02	0.202 ± 0.05
Odoro Okoko	8.026527	4.560671	0.045 ± 0.01	45 ± 11.00	0.0552 ± 0.01	0.193 ± 0.05
ICRP 2003 recommended value			0.113	84.00	1.00	0.29

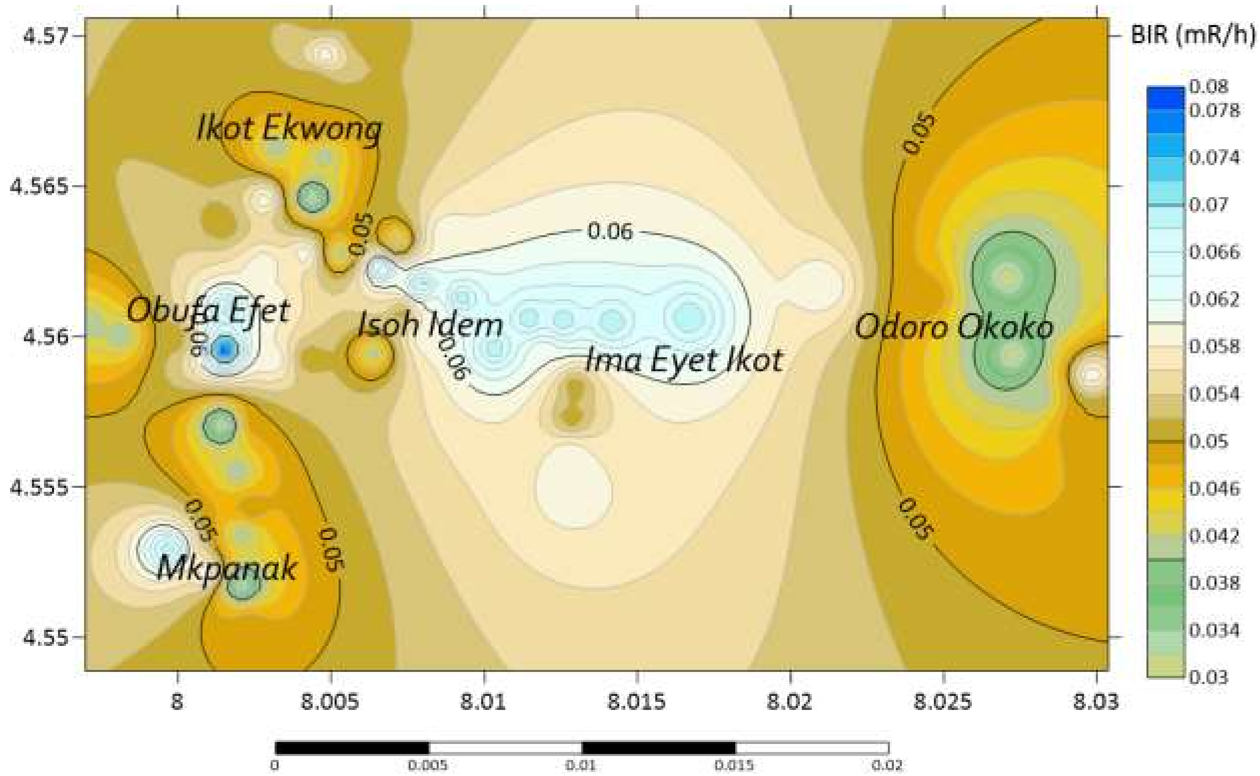

Figure 1. Contour map of the study area showing the exposure rate distribution across the study location.

4. DISCUSSION

The mean ambient exposure rates in the sampled communities in Ibeno were found to be between 0.045 ± 0.01 to 0.063 ± 0.01 μSv/h and the highest mean was observed in the Ima Eyet Ikot Community and the lowest in the Odoro Okoko Community (Table 7). These values are lower than the recommended reference level of 0.113 μSv/h (ICRP, 2003) which means that the ambient gamma radiation environment in the study area is not currently at a level that is beyond the internationally accepted limits of public exposure.

The difference in spatial exposure rates within the communities can be explained by the differences in the history of oil spills, closeness to oil infrastructure, the soil structure, and the redistribution of sediments along the Ibeno River. The increased exposure rates among the Ima Eyet Ikot and Obufa Eyet communities could be a result of greater accumulation of NORMs because of the recurrent contamination of the crude oil and hydrocarbon-related practises, which are known to release radionuclides stored in the subsurface formations into the surface.

The exposure rates achieved in this study are lower than those achieved in the oil-impacted and high natural background radiation regions of the world when compared with those of the world. As an example, Sharma et al. (2023) have found outdoor gamma dose rates between 0.09 and 0.29 μSv/h in the Himalayan region of India, and Masoumi and Keshtkar (2021) have found a mean outdoor dose rate of 0.111 μSv/h in Iran - almost twice the mean values in the current study. On the same note, in mining and quarry sites in Nigeria, exposure has been reported to be significantly higher, with the highest rate of 0.19 mR/h being recorded in Ebonyi State (Echeweozo and Ugbede, 2020).

The exposure rates here however are similar to those achieved in other regions of the Niger Delta. The reported exposure rates of 0.0095-0.022 mR/h, as reported by Biere et al. (2024) and Usman et al. (2022), fall within the relatively moderate levels of radiation in the given work. These results indicate that despite the fact that the background radiation can be improved because of oil exploration activities, the background radiation in Ibeno communities is not exceeding radiology tolerable levels.

The dose rates of the study area were 45 ± 11 to 63 ± 8 nGy/h with the community average of about 53 nGy/h. These values are lower than the world average value of 59 nGy/h outdoor absorbed dose rate given by UNSCEAR (2020), which shows that the area of the study has relatively low levels of external gamma radiation despite being oil producing.

The highest mean absorbed dose rate was observed in Ima Eyet Ikot (63 ± 8 nGy/h) with a slightly higher value than the UNSCEAR world average and Odoro Okoko with the lowest rate of 45 ± 11 nGy/h. It is possible that the elevated level of absorbed dose rates in certain areas is associated with the TENORM concentration in soils and sediments contaminated by oil, since the extraction of crude oil tends to concentrate the radium isotopes in the surface media.

In comparison, Zeb et al. (2020) found outdoor absorbed dose rates of 74 ± 30 nGy/h in Pakistani cities, whereas Gogoi et al. (2024) and Shashikumar et al. (2022) found the average outdoor values of 65.7 ± 5.8 nGy/h and 80.39 ± 2.6 nGy/h, respectively. The values are significantly higher than those obtained in the current study. Likewise, Ilugo et al. (2025) came up with mean absorbed dose rates of more than 100 nGy/h in some regions of Delta State, Nigeria.

The relatively low dose rates of the absorbed dose in the Ibeno communities indicate that although the oil related activities could affect the background radiation levels, the geological formations and sediment properties in the area are dominant in moderating the distribution of radionuclides.

The determined values of the annual effective dose equivalent (AEDE) were between 0.0552 and 0.0773 mSv/y with the highest mean value of 0.0773 mSv/y being again recorded by Ima Eyet Ikot. The AEDE values measured in this paper are all very low relative to the ICRP (2003) public exposure limit of 1.0 mSv/y, which means that the radiological risk associated with outdoor gamma exposure is very low.

The values of AEDE reported here are quite low compared to those reported in high background radiation areas when compared with international values. Masoumi and Keshtkar (2021) found an effective dose of 0.817 mSv/y in Iran, and Paul et al. (2025) found higher effective doses around coalfields in India because of increased terrestrial gamma radiation. The comparatively low AEDE values in the current study indicate that the chronic exposure of the external gamma in the Ibeno communities is not beyond the radiological safe limits.

However, the accumulative effect of radiation exposure during a long duration of time, and the presence of other exposure routes like consumption of contaminated water and food crops, highlights the necessity of continuous monitoring of the environment, especially in oil producing areas where recurrent spills can slowly increase the levels of radionuclides.

The values of excess lifetime cancer risk (ELCR) were estimated to be between 0.193 x 10^{-3} and 0.27 x 10^{-3}, and the highest risk was in Ima Eyet Ikot and the lowest in Odoro Okoko Community. These values are less than the ICRP nominal risk coefficient standard of 0.29 x 10^{-3}, and it implies that there is low likelihood of cancer induction by outdoor exposure to gamma radiations in the study region.

Relatively, Masoumi and Keshtkar (2021) measured an ELCR of 2.85 × 10^{-3}, a magnitude more than that of the results in this work, by an order of magnitude. On the same note, Zeb et al. (2020) have found that the lifetime cancer risks are high in the urban centres of Pakistan due to the increased gamma dose rates both indoors and outdoors. Research that has been done in the mining and quarry area in Nigeria has also reported much higher values of ELCR as a result of increased radiation fields (Echeweozo & Ugbede, 2020).

The low ELCR values that were realised in the present study suggest that external gamma radiation might not be a major carcinogenic hazard in the Ibeno communities. Nevertheless, given the fact that the environment in question is oil-polluted, internal exposure routes (e.g., consumption of radionuclidecontaminated water, inhalation of radon) might also pose some extra risks, which were not covered by this study.

5. CONCLUSION

This study assessed environmental gamma radiation levels in selected crude oil–impacted communities along the Ibeno River in Akwa Ibom State, Nigeria, with the aim of evaluating potential radiological health risks to the exposed population. The measured exposure rates, absorbed dose rates, annual effective dose equivalents, and excess lifetime cancer risk values showed noticeable spatial variations across the study area, reflecting differences in oil spill history, land use, and environmental characteristics. Nevertheless, all evaluated radiological parameters remained below internationally recommended limits set by the International Commission on Radiological Protection (ICRP) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR). Although some communities exhibited relatively higher values, particularly in areas with recurrent crude oil contamination, the overall radiation levels indicate a low immediate radiological risk from external gamma exposure. The estimated excess lifetime cancer risk values further suggest that the probability of radiation-induced cancer due to outdoor exposure is minimal. However, given the cumulative nature of ionizing radiation and the persistent occurrence of oil-related activities in the area, long-term exposure cannot be completely disregarded. Therefore, continuous environmental radiation monitoring is strongly recommended, alongside the assessment of internal exposure pathways such as ingestion and inhalation. These findings provide baseline radiological data for the Ibeno area and are valuable for environmental management, regulatory enforcement, and public health planning in oil-producing regions of the Niger Delta.

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