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Original Research Article

Background Radiation Levels of Residential Buildings within Selected Oil and Gas Eploration Communities in Andoni LGA of Rivers State

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ABSTRACT

Background radiation is a persistent component of the environment, originating from natural and artificial sources. This study assessed background radiation levels in residential buildings across selected oil and gas exploration communities in Andoni Local Government Area (LGA), Rivers State, Nigeria. A cross-sectionalprospective survey was conducted in 350 residential buildings across 35 communities in seven districts of the LGA. Indoor and outdoor radiation levels were measured in situ using a calibrated Radiation Alert Ranger dosimeter held one meter above ground level. Three readings were taken at each location and averaged. Annual indoor and outdoor effective dose rates were calculated using standard occupancy factors. Data were analyzed using Statistical Package for Social Sciences, SPSS, version 21.0 (IBM Corp. Armonk, NY, USA, 2012). Data were described using mean ± SD, frequency tables and bar charts. One way analysis of variance (ANOVA) was used to compare mean background radiation levels among the communities and within strata while mean indoor and outdoor effective dose with recommended dose limits recommended by international regulatory bodies. Results showed slight variations in background radiation across districts. Agwutobolo recorded the highest effective dose (0.2836 mSv/y) and Unyeada the lowest (0.1787 mSv/y). The lungs received the highest organ absorbed dose (0.034032 mSv/y), while the thyroid received the lowest (0.007148 mSv/y). Excess Lifetime Cancer Risk (ELCR) ranged from 1.13×10^{-3} to 7.13×10^{-4}. All measured values remained well below the public exposure limit of 1.0 mSv/y recommended by the International Commission on Radiological Protection (ICRP) and the global average of 2.4 mSv/y reported by UNSCEAR. The findings indicate that residents of these oil-producing communities are not at significant radiological risk from background radiation levels. The study provides a useful baseline for continuous environmental monitoring and can inform policy-making on radiation protection and community health management in oil-producing regions.

Keywords: Background radiation, Outdoor annual dose, radiation protection

1.0 INTRODUCTION

Radiation from natural sources is an unavoidable part of the Earth's environment, stemming from cosmic interactions, radioactive minerals in the ground, and even biological processes within humans. Under normal conditions, these radiation levels remain low and pose minimal risk. However, in areas where industrial activities such as oil and gas exploration are widespread, these levels can be disrupted and enhanced due to the disturbance of naturally occurring radioactive substances [1]. The Niger Delta in Nigeria, a major hub for petroleum extraction, presents environmental challenges due to its intense resource development. Andoni Local Government Area (LGA) in Rivers State lies within this region and houses in close proximity to oil exploration zones may experience higher radiation exposure. This closeness raises valid health concerns, especially regarding indoor radiation exposure, as residential spaces are where individuals spend the majority of their time.

Background radiation levels is a consistent presence in our environment originating from both artificial and natural sources. It can be defined as the radiation produced by these artificial and natural sources. In other words, the constant, natural level of ionizing radiation in the environment is known as background radiation levels. In the absence of a specific radiation source, the total radiation dose received at a location is recorded as background radiation levels [2]. Because the globe is naturally radioactive, it is essential to monitor background radiation levels in human-inhabited environments to prevent excessive public exposure [3,4]. It is estimated globally that 82 % of human absorbed doses occurs out of control following natural and artificial sources of background radiation levels like cosmic, terrestrial exposure from inhalation or intake radiation sources, medical exposures, nuclear weapon testing, etc [5].

It is of interest to note that, there is no place on earth devoid of natural radioactivity [6,7]. More than sixty radionuclides can be found in the environment which can be divided into three general categories. They are, primordial (which formed before the earth creation), cosmogenic (formed as a consequence of ray interactions), and human produced. Radionuclides are found naturally in air, soil, water and food. Natural radioactivity is common in rocks and soil that constitute the planet earth in water and oceans and in building materials and home. Natural radioactivity has great ionizing radiation effect on the world population due to its presence in our surrounding at different amounts, thus man by the very nature of his environment is exposed to varying amount of radiation with or without his consent. For instance, materials used for building (soil and rock) are major means of migration for the transfer of radionuclides into the environment. Natural radioactivity in soil is mainly due to ^{238}U, ^{40}K, ^{226}Ra which cause internal and external radiological hazards due to emission of gamma rays and inhalation of radon and its daughters [4]. Radon-222 (^{222}Rn) results from radioactivity of Uranium-238 and itself decays with a half-life of 3.82 days. When it is inhaled it penetrates into the lungs causing lung cancer as well as gastrointestinal tract cancer [8].

The earth crust is rich with the natural sources of background radiation, which include natural radionuclides and their progenies and the host of these natural occurring sources of background radiation are mineral ores, rocks and soil [9]. With the large mass of mineral ore deposits and rocks fairly spread across different regions of Nigeria, many local mining and rock quarrying outfits have been set up in these regions. Rock quarrying which involves excavation of deep buried and outcrop rocks followed by crushing into various sizes can redistribute radionuclides in quarry dust, soil and air have the capacity of increasing the background radiation levels and radiation dose rate of workers and inhabitants of immediate environment. The rock quarry products which are extensively employed as part of materials in building and road construction, can as well increase the indoor exposure of a population to the radiations emitted from buildings [10]. Natural radionuclides and potential toxic elements contaminated in the rocks during quarrying can find their way to the human internal organs through inhalation of dust particles suspended in air and ingestion of contaminated water and food crops cultivated in soil of immediate environment [11]. Radionuclides present in the environment may enter the human body through air, food and water, thereby adversely affecting human health at higher radiation dose levels. The levels of background radiation vary significantly from area to area and hence radiation doses received by the general. This variation can as well result from activities of oil and gas extraction and exploration [3,4].

According to UNSCEAR report [4], it has been established globally of the fact that, the total annual effective dose is 2.4 mSv/y. In Nigeria many studies have been conducted to determine background radiation levels and results from these studies showed variation in the levels of background radiation doses among states and different locations within a state [6,12,13,14]. From the literature search, there was no study on background radiation levels in Andoni LGA of Rivers State, hence the reason for this study. This study is aimed at assessing the background radiation levels in some residential buildings of selected oil and gas exploration communities of Andoni LGA of Rivers State, Nigeria. The outcome is expected to provide foundational data for radiation monitoring, support regulatory decision-making, and help ensure the health and safety of residents in the area.

2.0 MATERIALS AND METHODS

2.1 Study Design

A cross-sectional prospective survey design was adopted for this study to evaluate the background radiation levels of residential buildings within selected oil and gas exploration communities of Andoni LGA of Rivers State.

2.2 Area of Study

This study was conducted in Andoni LGA of Rivers State. Andoni LGA is located between Latitude 4.54917 and 4^0 32' 57" North and Longitude 7.44639 and 7^0 26' 47" East. Andoni has a land area of about 23,300 hectares or 233.00 km^2 (89.96 square miles) with a population of about 311,500 inhabitants, population density of 1,336.9 / km^2 (3,462.6 square miles). [15]. This area experience dry season from November to February whereas rainy season is from March to October. The LGA harbours many oil and gas exploration communities with consequent environmental pollution going on as a result of oil spillages.

2.3 Target population of study

The population for this study comprised 97 oil and gas exploration communities in Andoni LGA.

2.4 Sample Size

A sample size of 350 buildings was used for study. This was the number that met the inclusion criteria out of the 384 calculated using Magnani Robert [16] formula for unknown population: $n = Z^2 \times pq/d^2$, where n = minimum sample size, Z = the standardized – Z score = 1.96 (at 95% confident interval), p = proportion with the desired characteristic(p = 0,5 when not known) q – 1 – p = 0.5, d = tolerable error, = 0.05. Hence $N = [(1.96)^2 \times 0.5 \times 0.5] / 0.05^2 = [(3.8416) \times (0.25)] / 0.0025 = 0.9604/0.0025 = 384.16 = 384$

2.5 Sampling Technique

Multi-stage sampling technique was adopted. Firsly, stratified sampling method was used to stratify the 97 oil and gas exploration communities into seven (7) strata corresponding to the seven districts in Andoni LGA namely; Isiokwan, Okwan-aja, Unyeada, Asarama, Ataba, Ngo urban and Agwut-Obolo. Secondly, purposive sampling was used to select 5 communities from each stratum where the oil and gas exploration was highest, and then random sampling technique was adopted to select 11 buildings from each of the communities making it a total of 385 buildings.

2.6 Inclusion criteria
A building was included in the survey if:
1. It is within 150 – 300ft (45 – 90m) of an oil and gas exploration company, and
2. It is separated from each other by at least 6 – 12ft (1.8 – 3.6m) according to (Quora.com, 2025
3. The owner gives consent for it to be surveyed

2.7 Exclusion criteria
Buildings were excluded if:
i. Outside 45–90 m from an oil facility.
ii. Separation from neighbouring buildings was <1.8 m.
iii. Owner declined consent.

2.8 Ethical consideration
Ethical approval for the study was obtained from the Rivers State Hospital Management Board, Research and Ethics Committee, Port-Harcourt (RSHMB/RSHREC/2024/023). Approval consent was obtained from the traditional rulers of the study communities. Inform consent was obtained from the owner/residents of the buildings.

2.9 Instruments and Procedures of Data Collection
2.9.1 Instruments
Instruments that were used for this research are as follows
a) Area survey dosimeter (Name-Radiation Alert Ranger, model-Ranger, Serial number-R313213, Manufacturer-SE INTERNATIONAL INC calibration date and due date - 29/11/2023 and 28/11/2024)
b) Data colletion sheet
c) Stationery (biro)
d) Measuring Tape
e) Umbrella
f) Ordinary Hand gloves and
g) Nose / face masks.

2.9.2 Validity / Reliability
A well calibrated and certified dosimeter was gotten from the National Institute of Radiation Research (NIRR), University of Ibadan. This is a Nigerian secondary standard laboratory and a division of the Nigeria Nuclear Regulatory Authority (NNRA) and certified by the International Atomic Energy Agency (IAEA).

2.9.3 Procedure for data collection
The method of data collection was adopted from the study previously done by [17,18,19,20]. In-situ background radiation measurement and exposure rate of the selected areas of Andoni LGA was conducted using a hand-held radiation survey meter (Radiation Alert Ranger Dosimeter) Measurement was taken 1m from ground level which is standard recommended height for such measurement [18]. Owing to the unstable nature of background radiation levels [21], three repeated measurements at interval of three minutes were taken for each location with the detector window that turned to different directions so as to capture the radiation coming from the different directions. Each measurement lasted for 60seconds. Thereafter, the average value from the three measurements was computed and was recorded as the average background exposure level for that location. For the indoor measurements, the radiation survey meter was held following the standard recommended height of 1m above the floor and 1m from the wall at each location. A similar procedure was used for the outdoor measurement location. The relevant conversion was done to obtain the annual indoor effective dose rate (IAEDR) and the annual outdoor effective dose rate (OAEDR). The indoor annual effective rate (IAEDR) and the outdoor annual effective dose rate (OAEDR) (in mSv/y) was computed using the respective recommended indoor and outdoor occupancy factors of 0.8 and 0.2 respectively [4]. The hourly dose rate (μSv/h) was converted to the annual dose

rate (mSv/y) as in the following equations below:

Annual dose rate (mSv/y) = X (mSv/h) × T × OF

Where; X = hourly dose rate, T = total number of hours in a year (8760 hours), and OF = occupancy factor (indoor = 0.8 and outdoor = 0.2). Based on 24 hours a day and 365 days in a year, the number of ours in a year was 24 × 365 = 8760 hours

Therefore, IAEDR (mSv/y) = X (mSv/y × 8760 × 0.8 × 10^{-3}) and OAEDR (mSv/y) = X (mSv/y × 8760 × 0.2 × 10^{-3})

The total annual effective dose rate (AEDR) was computed as: AEDR=IAEDR+OAEDR

IAEDR = Indoor annual effective dose rate

OAEDR = Outdoor annual effective dose rate

2.9.4 Excess Lifetime Cancer Risk (ELCR)

ELCR was calculated using the equation: ELCR= AEDR (mSv/y) × DL× RF

Where; AEDR = total average annual effective dose (mSv/y)

DL = average duration of life (70 years)

RF = risks factor per Sv. RF = 0.057 Sv^{-1} (ICRP risk factor for stochastic effects in the public)

ELCR = a term used to estimate the difference between the proportion of persons who will develop or die of cancer (per sievert) in an exposed population compared to the people in a similar population that were not exposed to radiation.

2.9.5 Organ Absorbed Doses

Organ doses were calculated according to ICRP tissue-weighting factors (ICRP Publication 103):

HT=AEDR ×wT, where wT is the tissue-weighting factor for organ T. Lungs: 0.12, Colon: 0.12, Gonads: 0.08, Bone marrow: 0.12, Thyroid: 0.04. This method was applied directly to the measured AEDR for each district.

2.10 Method of Data Analysis

The data collected was analyzed using Statistical Package for Social Sciences (IBM SPSS) version 21.0 (IBM Corp. Armonk, NY, USA, 2012). . Descriptive statistics (mean, standard deviation, frequency tables, charts) were used to summarize the data, while inferential statistics (Chi-square tests) assessed relationships between variables. The results for IAEDR, OAEDR, AEDR, ELCR, and organ absorbed doses were presented in comparative tables by district.

3.0 RESULTS

3.1 To measure and record the background radiation levels in selected areas of Andoni LGA

From table 1, the measured average mean indoor and outdoor background radiation levels in Ataba District of Andoni L.G.A in Rivers State are 0.0949±0.070mSv and 0.0967±0.127mSv respectively. The mean indoor and outdoor background radiation levels for Isijoro are 0.1913±0.275mSv and 0.0858±0.022mSv respectively. Mean indoor and outdoor background radiation levels in Iyoba in Ataba District are 0.0877±0.021mSv and 0.0792±0.026mSv respectively (Table 1). The mean indoor and outdoor background radiation levels in some communities of Agwutobolo District of Andoni L.G.A in Rivers State are Agana (indoor=0.0869±0.016mSv and outdoor=0.1095±0.022mSv), Isiama (indoor = 0.0960±0.019 and outdoor = 0.1149±0.016mSv) and Oyorokoto (indoor = 0.1316±0.018mSv and outdoor = 0.2171±0.033mSv) (Table 2). The average mean values for indoor and outdoor background radiation levels in Agwutobolo District are 0.1466±0.083mSv and 0.1369±0.021mSv respectively (Table 2).

From table 3.3, the mean indoor and outdoor background radiation levels in some communities of Asarama District of Andoni L.G.A in Rivers State are Asarama-Ija (indoor = 0.0873±0.021mSv and outdoor = 0.0972±0.026mSv), Inyong-Orong (indoor = 0.0756±0.021mSv and outdoor =

0.1019±0.019mSv) and Iwoma (indoor = 0.0913±0.029mSv and 0.0921mSv). The average mean indoor and outdoor background radiation levels in Asarama District are 0.0830±0.024mSv and 0.0983±0.021mSv (Table 3).

The mean indoor and outdoor background radiation levels of some villages in Ngo-Urban District of Andoni L.G.A in Rivers State are Ebukuma (indoor = 0.0803±0.013mSv and outdoor = 0.0871±0.018mSv), Ekede (indoor = 0.1826±0.243mSv and outdoor = 0.1969±0.030mSv) and Ngo (indoor = 0.0852±0.014mSv and outdoor = 0.0606±0.014mSv) with average mean indoor and outdoor background radiation levels of 0.103±0.061mSv and 0.0114±0.021mSv respectively (Table 4). The average means indoor and outdoor background radiation levels in Okwanaja District of Andoni L.G.A in Rivers State are 0.0765± 0.021mSv and 0.1171±0.065mSv respectively (Table 5).

The mean indoor and outdoor background radiation levels in some communities of Unyeada District of Andoni L.G.A in Rivers State are Egbormung (indoor = 0.0683±0.015 and outdoor = 0.0802±0.026mSv), Polokiri (indoor = 0.0804±0.027mSv and outdoor = 0.1060±0.017mSv) and Isiodum town (indoor = 0.0901±0.017mSv and outdoor = 0.1022±0.213mSv) with average mean indoor and outdoor background radiation levels of 0.0806±0.019mSv and 0.0982±0.062mSv respectively (Table 6)

From table 3.7, the mean indoor and outdoor background radiation levels in some communities of Isiokwan Districts are Ajakajak (indoor = 0.0780±0.016mSv and outdoor = 0.0863±0.024mSv), Okukpo (indoor = 0.0987±0.014mSv and outdoor = 0.1603±0.043mSv), and Udung-Ama (indoor = 0.2163±0.027mSv and outdoor = 0.1133±0.036mSv) with average mean indoor and outdoor background radiation levels that are 0.107±0.069mSv and 0.01119±0.029mSv respectively (Table 7)

Table 1: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Ataba District

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Agbakaroma	0.0706±0.021	0.0754±0.179	0.146±0.2
Ataba	0.0700±0.015	0.1563±0.273	0.2263±0.288
Isijoro	0.1913±0.275	0.0858±0.022	0.2771±0.297
Isita	0.0550±0.019	0.0867±0.133	0.1417±0.152
Iyoba	0.0877±0.021	0.0792±0.026	0.1669±0.047
Mean±SD	0.0949±0.070mSv	0.0967±0.127mSv	0.1916±0.197mSv

Table 2: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Agwutobolo District.

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Agana	0.0869±0.016	0.1095±0.022	0.1964±0.038
Ilotombi	0.3230±0.346	0.1206±0.016	0.4436±0.362
Isiama	0.0960±0.019	0.1149±0.016	0.2109±0.035
Oyorokoto	0.1316±0.018	0.2171±0.033	0.3487±0.051
Uyengala	0.0957±0.016	0.1225±0.017	0.2182±0.033
Mean±SD	0.1466±0.083	0.1369±0.021	0.2836±0.104

Table 3: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Asarama District

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Asarama	0.0649±0.021	0.0926±0.022	0.1575±0.043
Asarama-ija	0.0873±0.021	0.0972±0.026	0.1845±0.047
Asarama-toru	0.0960±0.026	0.1027±0.019	0.1987±0.045
Inyong-orong	0.0756±0.021	0.1019±0.019	0.1775±0.04
Iwoma	0.0913±0.029	0.0921±0.019	0.1883±0.048
Mean±SD	0.0830±0.024	0.0983±0.021	0.1813±0.045

Table 4: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Ngo-Urban District

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Ama Otiga	0.0887±0.016	0.1146±0.019	0.2033±0.034
Ebukuma	0.0803±0.013	0.0871±0.018	0.1674±0.031
Ekede	0.1826±0.243	0.1969±0.030	0.3795±0.273
Ngo	0.0852±0.014	0.0606±0.014	0.1452±0.028
Ukwa	0.0800±0.017	0.0977±0.023	0.1777±0.04
Mean±SD	0.1034±0.061	0.1114±0.021	0.2146±0.081

Table 5: Mean Indoor and Outdoor Background Radiation Levels in Okwanaja District of Andoni LGA in Rivers State.

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Asuk-Oyet	0.0724±0.013	0.0940±0.015	0.1664±0.028
Asukama	0.0973±0.041	0.1046±0.025	0.2019±0.066
Ikuru	0.0651±0.013	0.1090±0.040	0.1741±0.053
Okoile	0.0650±0.015	0.0883±0.019	0.1533±0.034
Okotobonile	0.0825±0.021	0.1895±0.227	0.272±0.248
Mean±SD	0.0765±0.021	0.1171±0.065	0.1939±0.086

Table 6: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Unyeada District

Communities	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Amaikpo	0.0862±0.021	0.0967±0.021	0.1829±0.042
Egbormung	0.0683±0.015	0.0802±0.026	0.1485±0.041
Polokiri	0.0804±0.027	0.1060 ±0.017	0.1864±0.044
Isiodum Town	0.0901±0.017	0.1022±0.213	0.1923±0.23
Unyeada	0.0783±0.019	0.1053±0.031	0.1836±0.05
Mean±SD	0.0806±0.019	0.0982±0.062	0.1787±0.081

Table 7: Mean Indoor and Outdoor Background Radiation Levels (mSv) in Isiokwan District

	Indoor Mean±SD	Outdoor Mean±SD	Total Mean±SD
Ajakajak	0.0780±0.016	0.0863±0.024	0.1643±0.04
Ibot –Irem	0.0594±0.012	0.0909±0.017	0.1503±0.029
Ikwuoke	0.0826±0.030	0.1085±0.029	0.1911±0.059
Okukpo	0.0987±0.014	0.1603±0.043	0.259±0.057
Udung Ama	0.2163±0.276	0.1133±0.036	0.3296±0.312
Mean±SD	0.107±0.069	0.1119±0.029	0.2189±0.099

3.2 To identify any local variations in the mean background radiation levels within Andoni LGA

The total mean indoor and outdoor background radiation levels across the various districts are Ataba (0.1916mSv), Agwutobolo (0.2836mSv), Ngo-Urban (0.2146mSv), and Unyeada (0.1787mSv) (Figure 1)

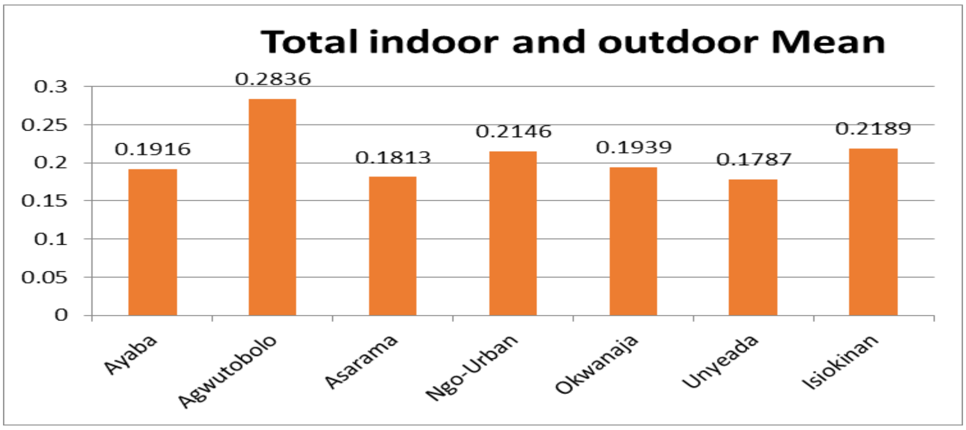

Figure 1: Barchart showing total mean Background Radiation levels (mSv) among the districts in Andoni LGA of Rivers State.

3.3 To compare the mean background radiation levels among the strata

There is no statistically significant mean difference in the indoor background radiation levels across the different districts in Andoni L.G.A of Rivers State at (F = 2.562, P = 0.02) (Table 8). There is no statistically significant mean difference in the outdoor background radiation levels across the various districts of Andoni L.G.A in Rivers State at (F = 2.187, P = 0.04) (Table 9)

Table 8: ANOVA table showing the comparison of the mean indoor Background Radiation Levels (mSv) among the districts.

Districts	N	Mean±SD	Std Error	Lower Bound	Upper Bound	Df	F	p-value
Ataba	52	0.0949±0.129	0.018	0.058	0.132			
Agwutobolo	50	0.1466±0.174	0.024	0.097	0.197			
Asarama	49	0.0830±0.026	0.004	0.075	0.090			
Ngo-Urban	50	0.1034±0.113	0.016	0.071	0.135	6	2.562	0.02
Okwanaja	50	0.0746±0.258	0.004	0.069	0.084			
Unyeada	49	0.0807±0.021	0.003	0.075	0.087			
Isiokinan	50	0.1070±0.132	0.019	0.069	0.145			
Total	350	0.099±0.108	0.006	0.088	0.10			

Table 9: Tukey's HSD Test for Mean Indoor Background Radiation Levels among Districts

Comparison	Mean Difference (mSv)	Std. Error	p-value	95% CI Lower	95% CI Upper	Significant (α = 0.05)
Agwutobolo – Ataba	0.0517	0.031	0.571	-0.040	0.144	No
Asarama – Ataba	-0.0119	0.031	0.999	-0.104	0.080	No
Ngo-Urban – Ataba	0.0085	0.031	1.000	-0.084	0.101	No
Okwanaja – Ataba	-0.0203	0.031	0.995	-0.112	0.072	No
Unyeada – Ataba	-0.0142	0.031	0.999	-0.106	0.078	No
Isiokinan – Ataba	0.0121	0.031	0.999	-0.080	0.105	No
Asarama – Agwutobolo	-0.0636	0.031	0.289	-0.156	0.029	No
Ngo-Urban – Agwutobolo	-0.0432	0.031	0.731	-0.135	0.049	No
Okwanaja – Agwutobolo	-0.0720	0.031	0.158	-0.164	0.020	No
Unyeada – Agwutobolo	-0.0659	0.031	0.262	-0.158	0.026	No
Isiokinan – Agwutobolo	-0.0396	0.031	0.817	-0.131	0.052	No
Ngo-Urban – Asarama	0.0204	0.031	0.994	-0.072	0.113	No
Okwanaja – Asarama	-0.0084	0.031	1.000	-0.101	0.084	No
Unyeada – Asarama	-0.0023	0.031	0.985	-0.068	0.116	No
Isiokinan – Asarama	0.0240	0.031	0.964	-0.121	0.063	No
Okwanaja – Ngo-Urban	-0.0288	0.031	0.991	-0.115	0.069	No
Unyeada – Ngo-Urban	-0.0227	0.031	1.000	-0.089	0.096	No
Isiokinan – Ngo-Urban	0.0036	0.031	1.000	-0.086	0.098	No
Unyeada – Okwanaja	0.0061	0.031	0.944	-0.059	0.124	No
Isiokinan – Okwanaja	0.0324	0.031	0.977	-0.066	0.119	No

The analysis using Tukey's HSD test, following the one-way ANOVA ($F(6, 343) = 2.562$, $p = 0.02$), revealed that there were no statistically significant differences in mean indoor background radiation levels between any pair of districts at the 5% significance level. Although Agwutobolo District had the highest mean indoor radiation level (0.1466 mSv) and Okwanaja District the lowest (0.0746 mSv), the pairwise comparisons showed that these differences were not large enough to reach statistical significance following multiple comparisons. The 95% confidence intervals for all comparisons crossed zero, further confirming the absence of significant pairwise differences despite the overall ANOVA indicating a significant variation across districts.

Table 10: ANOVA table showing the comparison of the mean Background Radiation Levels (Outdoor) among the districts.

Districts	N	Mean±SD	Std Error	Lower Bound	Upper Bound	Df	F	p-value
Ataba	52	0.097±0.122	0.017	0.062	0.131			
Agwutobolo	50	0.1369±0.046	0.007	0.124	0.149			
Asarama	49	0.0973±0.021	0.003	0.091	0.103			
Ngo-Urban	50	0.1114±0.051	0.007	0.097	0.126	6	2.187	0.04
Okwanaja	50	0.1171±0.107	0.015	0.087	0.147			
Unyeada	49	0.0981±0.025	0.003	0.091	0.105			
Isiokinan	50	0.1119±0.039	0.006	0.100	0.123			

3.4 To compare the measured background radiation levels in relation to the standard values by International Organizations

Table 11: Comparison of Measured Background Radiation Levels with Standard Values by International Organizations

Districts	Indoor BGR (mSv/y) ± SD	Outdoor BGR (mSv/y) ± SD	Total Mean BGR (mSv/y) ± SD	ICRP Public Limit (mSv/y)	UNSCEAR Global Avg (mSv/y)
Ataba	0.0949 ± 0.070	0.0967 ± 0.127	0.1916 ± 0.197	1.0	2.4
Agwutobolo	0.1466 ± 0.083	0.1369 ± 0.021	0.2836 ± 0.104	1.0	2.4
Asarama	0.0830 ± 0.024	0.0983 ± 0.021	0.1813 ± 0.045	1.0	2.4
Ngo-Urban	0.1034 ± 0.061	0.1114 ± 0.021	0.2146 ± 0.081	1.0	2.4
Okwanaja	0.0765 ± 0.021	0.1171 ± 0.065	0.1939 ± 0.086	1.0	2.4
Unyeada	0.0806 ± 0.019	0.0982 ± 0.062	0.1787 ± 0.081	1.0	2.4
Isiokwan	0.1070 ± 0.069	0.1119 ± 0.029	0.2189 ± 0.099	1.0	2.4
Total	0.0989 ± 0.0240	0.1101 ± 0.0143	0.2089 ± 0.0363		

Table 12: Statistical Comparison of Background Radiation Levels with Standard Values by International Organizations

Comparison Standard	Hypothesized Mean (mSv/y)	t-value	df	p-value	Significance
ICRP Public Limit	1.0	–57.64	6	1.83×10^{-9}	Significantly lower
UNSCEAR Global Avg	2.4	–159.65	6	4.07×10^{-12}	Significantly lower

The background radiation levels in all districts are well below both the international public exposure limit given by ICRP and UNSCEAR. Statistically, the probability that the true mean is equal to or above these standards is extremely low (p <0.00000001). This confirms that residents and occupants of buildings in the LGA are radiologically safe.

3.5 To assess possible radiological impact following background radiation levels

Table 13, 14 and 15 indicate that residents of oil and gas exploration communities are safe radiologically.

Table 13: The Effective Dose (E) for each district

District	Indoor E (mSv/y)	Outdoor E (mSv/y)	Total E (mSv/y)
Ataba	0.1533	0.0383	0.1916
Agwutobolo	0.2269	0.0567	0.2836
Asarama	0.1450	0.0363	0.1813
Ngo-Urban	0.1717	0.0429	0.2146
Okwanaja	0.1551	0.0388	0.1939
Unyeada	0.1430	0.0357	0.1787
Isiokwan	0.1751	0.0438	0.2189

Table 14: Excess Lifetime Cancer Risk (ELCR) for Residents

Districts	Annual Effective Dose (mSv/y)	ELCR (unitless)
Ataba	0.1916	7.64×10^{-4}
Agwutobolo	0.2836	1.13×10^{-3}
Asarama	0.1813	7.23×10^{-4}
Ngo-Urban	0.2146	8.56×10^{-4}
Okwanaja	0.1939	7.74×10^{-4}
Unyeada	0.1787	7.13×10^{-4}
Isiokwan	0.2189	8.73×10^{-4}

Table 15: Organ absorbed dose

District	Indoor (mSv/y)	Outdoor (mSv/y)	Total E (mSv/y)	ELCR (unitless)	Lungs (mSv/y)	Colon (mSv/y)	Gonads (mSv/y)	Bone marrow (mSv/y)	Thyroid (mSv/y)
Ataba	0.153300	0.038300	0.191600	0.000764	0.022992	0.022992	0.015328	0.022992	0.007664
Agwutobolo	0.226900	0.056700	0.283600	0.001132	0.034032	0.034032	0.022688	0.034032	0.011344
Asarama	0.145000	0.036300	0.181300	0.000723	0.021756	0.021756	0.014504	0.021756	0.007252
Ngo-Urban	0.171700	0.042900	0.214600	0.000856	0.025752	0.025752	0.017168	0.025752	0.008584
Okwanaja	0.155100	0.038800	0.193900	0.000774	0.023268	0.023268	0.015512	0.023268	0.007756
Unyeada	0.143000	0.035700	0.178700	0.000713	0.021444	0.021444	0.014296	0.021444	0.007148
Isiokwan	0.175100	0.043800	0.218900	0.000873	0.026268	0.026268	0.017512	0.026268	0.008756

4.0 DISCUSSION

The background radiation levels across the various communities studied varies from one community to another with the mean values below the recommended values by UNSCEAR and ICRP. This implies that the people living in these communities were not exposed to high background radiations. This finding is in agreement with the findings of the studies conducted by Chiegwu *et al* [17] in Anambra State, Nigeria, Rilwan *et al* [22] in Nasarawa State, Nigeria and Tikyaa *et al* [23] in Katsina State, Nigeria which also reported varying values of indoor and outdoor background radiation levels across different areas measured.

In Chiegwu *et al* [17] study, which was conducted in Anambra State, Nigeria to evaluate background ionizing radiation exposure levels in industrial buildings in Nnewi across 40 buildings in four villages of Nnewi reported varying values for the indoor and outdoor background radiation exposures across the different buildings and vilaages respectively. Their mean values for indoor and outdoor background levels were also within the UNSCEAR and ICRP recommended values.

Also, Rilwan *et al* [22] study, which was carried out in Keffi General Hospital, Nasarawa State, Nigeria to determine the background radiation level, reported varying values of indoor and outdoor background radiation levels across the 10 offices used as the study area with the values within the UNSCEAR and ICRP recommended values also. In their study, the mean outdoor and indoor annual effective dose 0.08mSv/year and 0.3mSv/year respectively.

Also, in Tikyaa *et al* [23] study, which was carried out in Katsina State, Nigeria to evaluate the ambient background radaiation levels at the take off campus of Federal University Dutsin-Ma, reported varying values of indoor and outdoor background radiation levels respectively. Their overall average indoor and outdoor ambient background radiation levels at the take-off Federal University Dutsin-Ma were computed and found to be within the UNSCEAR and ICRP recommended values.

The result of this study revealed local variations in the values of background radiation levels across the studied strata with Agwut Obolo having the highest mean Background radiation levels, followed by Ngo-Urban and the least is Unyeada. This could be attributed to the different environmental activities taking place in the various geographical location. For instance, Agwutobolo and Ngo-Urban are close to oil companies where oil and gas exploration takes place and Unyeada their major their major occupation is dominated with fishing. This finding is similar to the results documented in Chiegwu *et al* [17] study, conducted in Nnewi Anambra State, reported indoor and outdoor background radiation levels of 0.8060 ± 0.056mSv/year and 0.2281 ± 0.020mSv/year. This finding is also in agreement with the results documented in Rilwan *et al* [22] study, Keffi General Hospital, Nasarawa State, reported indoor and outdoor background radiation levels of 0.17mSv/year and 0.04mSv/year

The result of this study revealed that there were no statistically significant mean differences in the values of background radiation levels across the various strata in Andoni. This shows that despite the fact that the readings obtained from the various districts were not the same, they are not statistically significantly different as they are within the acceptable recommended dose by UNSCEAR and ICRP.

The information from the study revealed that background radiation levels varied across the districts, with Agwutobolo recording the highest total mean radiation level (0.2836 mSv/y) and Unyeada the lowest (0.1787 mSv/y). This is consistent with the study of Chiegwu et al. [17] that opined varying values for indoor and outdoor background radiation exposures across different buildings and villages in Anambra State. Similarly, Rilwan et al. [22] found variations in indoor and outdoor background radiation levels across offices in Keffi General Hospital, Nasarawa State.

These variations are consistent with findings from other studies in Nigeria, which have also reported differences in background radiation levels across different states and locations. The variations in this study may be influenced by geological differences and localized human activities such as oil and gas exploration. This aligns with the understanding that factors like Earth's geological composition and human activities can contribute to geographical variations in background radiation levels. Based on the findings in this study it revealed that the total mean radiation values across the different district of Andoni LGA are within safe limits as recommended by international organizations thus the district with highest total mean radiation for indoor and outdoor radiation value (Agwutobolo) is 0.2836 ± 0.104mSv/y as compared to ICRP and UNSCEAR standard values of 1.0 and 2.4 respectively.

The assessment of radiological impacts in this study was crucial in determining whether the residents of selected oil and gas exploration communities in Andoni LGA are at any health risk due to background radiation exposure. The results showed district with the highest exposure indicating Agwutobolo, with an indoor dose of 0.2269 mSv/y and outdoor dose of 0.0567 mSv/y. Conversely, Unyeada recorded the lowest dose levels (0.1430 mSv/y indoor and 0.0357 mSv/y outdoor). These variations may be due to local differences in geology and the level of oil and gas exploration activities, which can disturb naturally occurring radioactive materials and increase environmental radiation levels [3,9]. Despite the differences, all recorded values remained within safe limits, both indoor and outdoor effective dose rates across all districts were below the international safety thresholds set by the International Commission on Radiological Protection (ICRP) at 1.0 mSv/y for the public, and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) global average of 2.4 mSv/y [4,24], implying no immediate radiological danger to the residents. The findings are consistent or in agreement with studies such as Chiegwu *et al*. [17] and Tikyaa *et al*. [23], who reported similar dose values in other parts of Nigeria and concluded that while current levels are within safety limits, regular monitoring and public awareness are essential, especially in areas with ongoing industrial activities.

CONCLUSION

The study show that the background radiation levels measured throughout Andoni LGA are considerably lower than the safety limits recommended by international bodies such as ICRP and UNSCEAR. Also, the study shows that the mean background radiation readings obtained from the various districts of the LGA were not the same. Despite the differences, both indoor and outdoor effective dose rates across all districts in Andoni LGA were below the international safety thresholds set by the International Commission on Radiological Protection (ICRP) at 1.0 mSv/y for the public, and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) global average of 2.4 mSv/y. The calculated effective indoor and outdoor background radiation suggest no significant radiological impact to the residents within the studied communities. While the current background radiation levels in Andoni LGA pose no short-term health risks, there is a need for continuous environmental monitoring, public education, and strict adherence to radiation safety guidelines. Nevertheless, it is important to maintain regular monitoring, especially in areas close to industrial activities to identify any potential long-term effects that could or may arise overtime. This will help prevent any future health complications that may arise from long-term exposure.

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