# Ambient Radiation Levels and Excess Lifetime Cancer Risk in Specialist Hospitals in Delta State, Nigeria

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***Abstract***
*This study evaluated ambient radiation levels and excess lifetime cancer risks (ELCR) across five specialist hospitals in Delta State, Nigeria. Measurements were performed at fifty locations across radiology, laboratory and clinical areas using a calibrated Geiger-Müller counter. Absorbed doses varied from 0.0084 to 0.0478 µSv/h and annual effective dose equivalents (AEDE) from 0.0893 to 0.1326 mSv/yr, all below than the ICRP public limit of 1.0 mSv/yr. However, 78% of the locations were above the UNSCEAR global average ELCR ($0.29 \times 10^{-3}$) and 2 radiology departments were above the ICRP upper acceptable limit ($1.0 \times 10^{-3}$). Dose rates were significantly higher in radiology departments than in clinical areas ($p < 0.0001$). While facilities comply with regulatory limits, systematic elevations above natural background levels warrant optimization under the ALARA principle. These findings provide essential baseline data for evidence-based radiation protection policies in Nigerian healthcare settings.*

**Keywords:** *Ambient radiation, effective dose, excess lifetime cancer risk, spatial variation, radiation protection*

## 1. Introduction

Ionizing radiation is an indispensable part of contemporary healthcare, with over 4.2 billion diagnostic radiology examinations, 40 million nuclear medicine procedures, and 8.5 million radiotherapy treatments performed each year globally (Chen, 2024; Amanda et al., 2023). However, radiation exposure has inherent biological risks, such as DNA damage and increased cancer risk (UNSCEAR, 2020; Tao et al., 2024). The International Commission on Radiological Protection (ICRP) recommends an annual limit of 1 mSv for the effective dose to members of the general public and an annual limit of 20 mSv averaged over five years for the effective dose to occupationally exposed workers (ICRP, 2007). ICRP Publication 147 also says that effective dose may be regarded as an approximate measure of potential risk, and that lifetime risks of cancer depend on age, sex and population group (ICRP, 2021; Harrison et al., 2021). However, the implementation of these standards in developing countries such as Nigeria is facing challenges including lack of monitoring equipment, insufficient staff training, weak regulatory compliance, and obsolete infrastructure (Archibong et al., 2025). However, recently, studies have shown gaps in the awareness and compliance of radiation safety in Nigerian hospitals. Umaru et al. (2024) found an average radiation knowledge score of 92% and compliance with safety procedures of 81% among hospital staff in Maiduguri, while Ingoniye and Aigbirior (2024) reported that while 88.3% of

the respondents correctly identified DNA damage as an effect of radiation exposure, there are significant deficits in the use of personal protective equipment. Ude et al. (2025) also reported that 30.1% of patients were unaware of warning signs of X-ray, which highlights the need for better patient education. Contradictory results have been published by previous Nigerian studies, with some reporting radiation levels within international standards (Abubakar et al., 2017; Omogunloye et al., 2021), while others reported high levels above recommended limits (Olowookere et al., 2022; Orlunta & Sokari, 2023). Recently, Isaac et al. (2025) reported AEDE values ranging from 0.970 to 2.880 mSv/yr and ELCR values ranging from 0.0027 to 0.0081 for radiotherapy workers in Abuja, while Omita et al. (2024) recorded effective doses ranging from 0.7204 to 0.9160 mSv for medical workers in South-Eastern Nigerian hospitals, all falling within ICRP limits. Delta State located in the Niger delta region of Nigeria is characterized by a high number of specialist hospitals and extensive oil and gas activities which may lead to an increase in the background radiation due to technologically enhanced naturally occurring radioactive materials (Avwiri et al., 2021). Indoor radiation assessment is still relevant, as a recent study by Aremu et al. (2024) reported radon concentrations of 12.09-58.52 Bq/m$^3$ and estimated annual effective doses of 0.529 mSv/yr in Nigerian hospital radiology facilities.
This study aims to evaluate the effective doses and ELCR from absorbed dose rates in selected specialist hospitals in Delta State.

## 2 Materials and Methods

### 2.1 Study Design and Area.

The study employed a cross-sectional survey which was carried out in five purposively selected specialist hospitals in Delta State, Nigeria (5°00′-6°30′ N, 5°00′-6°45′ E).

### 2.2 Sampling Procedure

Within each hospital, ten (10) measurement locations were systematically selected, giving a total of fifty (50) measurement points across the five facilities. This sample size is adequate for statistical analysis and provides a robust basis for generalization within the study area. Table 1 presents a summary of the hospital codes, sampling locations, their corresponding location codes, and the geographical coordinates recorded during the field measurements.

**Table 1: Sampling Locations, Location Codes, and GPS Coordinates**

| S/N | Hospital Codes | Location Code | Measurement Point | Latitude (°N) | Longitude (°E) |
|---|---|---|---|---|---|
| **1** | CHH | CHH-EM | Emergency Unit | 5.5407744 | 5.7628626 |
| | | CHH-ICU | Intensive Care Unit | 5.5411402 | 5.7628047 |
| | | CHH-IR | Imaging/Radiology | 5.5177185 | 5.7342451 |
| | | CHH-LB | Laboratory | 5.5409533 | 5.7630905 |
| | | CHH-PH | Pharmacy | 5.5306020 | 5.7581370 |
| | | CHH-PD | Pediatrics | 5.5407744 | 5.7628626 |
| | | CHH-OG | Obstetrics and Gynaecology | 5.5411402 | 5.7628047 |
| | | CHH-CD | Cardiology | 5.5409533 | 5.7630905 |
| | | CHH-PS | Psychiatric | 5.5306020 | 5.7581370 |
| | | CHH-OT | Surgery/Operating Theatre | 5.5177185 | 5.7342451 |
| **2** | GHW | GHW-EM | Emergency Unit | 5.5176907 | 5.7342983 |
| | | GHW-ICU | Intensive Care Unit | 5.5172082 | 5.7339293 |
| | | GHW-IR | Imaging/Radiology | 5.5167171 | 5.7345832 |
| | | GHW-LB | Laboratory | 5.5172061 | 5.7345537 |
| | | GHW-PH | Pharmacy | 5.5176907 | 5.7342983 |

| | | | | | |
|---|---|---|---|---|---|
| | | GHW-PD | Pediatrics | 5.5172082 | 5.7339293 |
| | | WCH-OG | Obstetrics and Gynaecology | 5.5171691 | 5.7349793 |
| | | GHW-CD | Cardiology | 5.5172061 | 5.7345537 |
| | | GHW-PS | Psychiatric | 5.5171691 | 5.7349793 |
| | | GHW-OT | Surgery/Operating Theatre | 5.5167171 | 5.7345832 |
| **3** | UGH | UGH-EM | Emergency Unit | 5.4926624 | 5.9635906 |
| | | UGH-ICU | Intensive Care Unit | 5.4926987 | 5.9837372 |
| | | UGH-IR | Imaging/Radiology | 5.4936385 | 5.9835208 |
| | | UGH-LB | Laboratory | 5.5172061 | 5.7345537 |
| | | UGH-PH | Pharmacy | 5.4590116 | 5.8681245 |
| | | UGH-PD | Pediatrics | 5.4926624 | 5.9635906 |
| | | UGH-OG | Obstetrics and Gynaecology | 5.4926987 | 5.9837372 |
| | | UGH-CD | Cardiology | 5.4936385 | 5.9835208 |
| | | UGH-PS | Psychiatric | 5.4590116 | 5.8681245 |
| | | UGH-OT | Surgery/Operating Theatre | 5.4926293 | 5.9847075 |
| **4** | LLH | LLH-EM | Emergency Unit | 5.552100 | 5.732200 |
| | | LLH-ICU | Intensive Care Unit | 5.552150 | 5.732250 |
| | | LLH-IR | Imaging/Radiology | 5.552200 | 5.732300 |
| | | LLH-LB | Laboratory | 5.552250 | 5.732350 |
| | | LLH-PH | Pharmacy | 5.552300 | 5.732400 |
| | | LLH-PD | Pediatrics | 5.552350 | 5.732450 |
| | | LLH-OG | Obstetrics and Gynaecology | 5.552400 | 5.732500 |
| | | LLH-CD | Cardiology | 5.552450 | 5.732550 |
| | | LLH-PS | Psychiatric | 5.552500 | 5.732600 |
| | | LLH-OT | Surgery/Operating Theatre | 5.552550 | 5.732650 |
| **5** | FMC | FMC-EM | Emergency Unit | 5.515400 | 5.721500 |
| | | FMC-ICU | Intensive Care Unit | 5.515450 | 5.721550 |
| | | FMC-IR | Imaging/Radiology | 5.515500 | 5.721600 |
| | | FMC-LB | Laboratory | 5.515550 | 5.721650 |
| | | FMC-PH | Pharmacy | 5.515600 | 5.721700 |
| | | FMC-PD | Pediatrics | 5.515650 | 5.721750 |
| | | FMC-OG | Obstetrics and Gynaecology | 5.515700 | 5.721800 |
| | | FMC-CD | Cardiology | 5.515750 | 5.721850 |
| | | FMC-PS | Psychiatric | 5.515800 | 5.721900 |
| | | FMC-OT | Surgery/Operating Theatre | 5.515850 | 5.721950 |

### 2.3 Instrumentation and Data Collection

Measurements were performed using a calibrated Radiation Alert® Monitor 200 Geiger-Müller counter (SE International, USA) with an energy response of 40 keV-3.0 MeV, detection range of 0.001-200 µSv/h and an accuracy of ±15% referenced to $^{137}Cs$ calibration standards. Coordinates were taken from a Garmin GPSMAP 64s receiver (±3 m accuracy). The height was kept constant at one metre by a tripod stand (S.E.international Inc., 2021). At each point, five consecutive readings were taken at one-minute intervals during active X-ray use. The detector was stabilized for 30 seconds before each reading. All measurements were conducted indoors.

### 2.4 Data Analysis

The mean absorbed dose rates were calculated as arithmetic means of five replicate readings (Omogunloye et al., 2021):

$$\overline{D} = \sum_{i=1}^{5} \frac{D_i}{5} \quad (1)$$

where represents the mean absorbed dose rate in µSv/h.
Annual effective dose equivalents were calculated using:

$$AEDE = \overline{D} \times 8760 \times 0.8 \times 0.001 \quad (2)$$

where 8760 represents annual hours, 0.8 is the indoor occupancy factor, and 0.001 converts µSv to mSv (ICRP, 2007).
Excess lifetime cancer risk was estimated using (Boumala et al., 2019:

$$ELCR = AEDE \times 70 \times 0.05 \times 10^{-3} \quad (3)$$

where 70 represents average lifespan in years, 0.05/Sv is the ICRP risk factor for fatal cancer, and $10^{-3}$ converts mSv to Sv.
Organ-specific equivalent doses were calculated using ICRP tissue weighting factors ($w_T$) for radiosensitive organs with $w_T \geq 0.04$ as shown in Table 2 (ICRP, 2007):

$$H_T = AEDE \times w_T \quad (4)$$

As recommended by ICRP Publication 147, effective dose may be considered an approximate indicator of possible risk, with the recognition that lifetime cancer risks vary by age, sex, and population group (ICRP, 2021; Harrison *et al.,* 2021). The ELCR estimates in this study should therefore be interpreted as population-average risk approximations rather than precise individual risk predictions.
Statistical analyses employed SPSS version 26, including one-way ANOVA and independent t-tests (α = 0.05). Spatial distribution was visualized using Surfer 16 contour mapping software.

## 3. Results and Discussion

### 3.1 Absorbed Dose Rates and Regulatory Compliance

Dose rates measured at all locations ranged from 0.0084 to 0.0478 µSv/h. Figure 1 presents the comparison of the mean annual effective dose across the hospitals with the ICRP and UNSCEAR limits and Table 2 presents comprehensive comparison data.
All AEDE values were below the ICRP limit for the public of 1.0 mSv/year. The highest individual AEDE (0.3349 mSv/yr) was recorded in the radiology department of FMC which was only 33.5% of the regulatory limit. Nevertheless, this safety margin is very high relative to the results of Omogunloye et al. (2021) (~0.12 mSv/yr in Makurdi hospitals) and Omita et al. (2024) (0.7204-0.9160 mSv for medical workers in South-Eastern Nigeria), but lower than the values of Abubakar et al. (2017) (0.60-2.01 mSv/yr) and Olowookere et al. (2022) (0.17-2.67 mSv/yr). Radon measurements in hospital radiology facilities in South-Western Nigerian presented in Aremu et al. (2024) indicated annual effective doses of 0.529 mSv/yr which agrees with the present study.

**Table 2: Comparative Radiological Parameters across Hospitals**

| Hospital | Min Dose (µSv/h) | Max Dose (µSv/h) | Mean ± SD Dose (µSv/h) | Mean ± SD AEDE (mSv/yr) | Mean ELCR ($\times 10^{-3}$) |
|---|---|---|---|---|---|
| **CHH** | 0.0092 | 0.0298 | 0.01640 ± 0.00640 | 0.1149 ± 0.0449 | 0.402 |
| **GWH** | 0.0096 | 0.0236 | 0.01478 ± 0.00427 | 0.1036 ± 0.0299 | 0.363 |
| **UGH** | 0.0084 | 0.0190 | 0.01274 ± 0.00369 | 0.0893 ± 0.0258 | 0.313 |
| **LLH** | 0.0104 | 0.0422 | 0.01718 ± 0.00969 | 0.1204 ± 0.0678 | 0.421 |
| **FMC** | 0.0106 | 0.0478 | 0.01892 ± 0.01110 | 0.1326 ± 0.0777 | 0.464 |
| **Mean** | **0.0084** | **0.0478** | **0.01600** | **0.1122** | **0.393** |

The difference in the mean dose rates between the highest and lowest locations, FMC and UGH respectively is 0.00618 µSv/h indicating significant facility-specific variation. The variation is likely a result of differences in the age of the equipment, maintenance culture, shielding integrity, room design, and building materials (Orlunta & Sokari, 2023; Ukerun-Akpesiri et al., 2023). The consistently lower values at UGH suggest that appropriate facility design can be used to achieve effective radiation protection, thus supporting the principle of optimization of the ALARA principle (ICRP, 2007; Clement et al., 2021).
The AEDE values obtained in this study (0.0893-0.1326 mSv/yr) are much lower than the ICRP public limit and the worldwide occupational averages, suggesting that general hospital staff in Delta State are exposed to relatively low occupational doses from ambient background radiation.

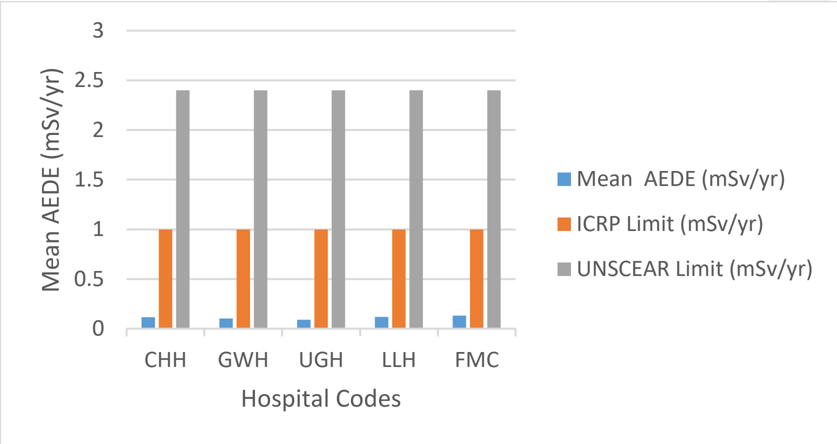


**Figure 2: Comparison of Mean Annual Effective Dose across Hospitals with the ICRP and UNSCEAR Limit.**

### 3.2 Excess Lifetime Cancer Risk

The mean ELCR values ranged from 0.313 × $10^{-3}$ (UGH) to 0.464 × $10^{-3}$ (FMC) with an overall mean value of 0.393 × $10^{-3}$ (Table 3). Figure 3 shows the comparison of mean ELCR values between hospitals and the global average of UNSCEAR and Figure 4 presents the comparison of mean radiological parameters in radiology departments in the facilities.
Notably, 78% of locations (39/50) were above the global average ELCR of 0.29 × $10^{-3}$ (UNSCEAR, 2000). The two radiology departments, Lily Hospital (1.035 × $10^{-3}$) and FMC (1.172 × $10^{-3}$) had values higher than the upper acceptable limit of the ICRP of 1.0 × $10^{-3}$.
The obtained ELCR results fall within the range reported by Ukerun-Akpesiri et al. (2023) (0.015-2.815 × $10^{-3}$) but are lower than the values reported by Olowookere et al. (2022) (0.57-6.07 × $10^{-3}$) and Orlunta and Sokari (2023) (0.64-0.77 × $10^{-3}$). Recently Isaac et al. (2025) reported ELCR values ranging from 0.0027 to 0.0081 (0.271%-0.807% lifetime cancer risk) for radiotherapy workers in Abuja, which were higher than the current findings due to the occupational nature of the exposure. This finding, consistent with studies applying similar protocols, further enhances the reliability of the present findings and supports the conclusion that general hospital areas exhibit lower cancer risks than dedicated radiology departments. Although all values are in the range of ICRP acceptable risk ($10^{-3}$ to $10^{-6}$), the systematic increase above the natural background level indicates that the present measures may not optimally protect according to the ALARA principle (ICRP, 2007; Clement et al., 2021).The two radiology departments with values above the ICRP upper limit constitute non-negligible stochastic risks for the workers exposed to it professionally, consistent with the finding of Ukerun-Akpesiri et al. (2023) that 40.9% of the diagnostic centres in Warri exceeded the UNSCEAR threshold.

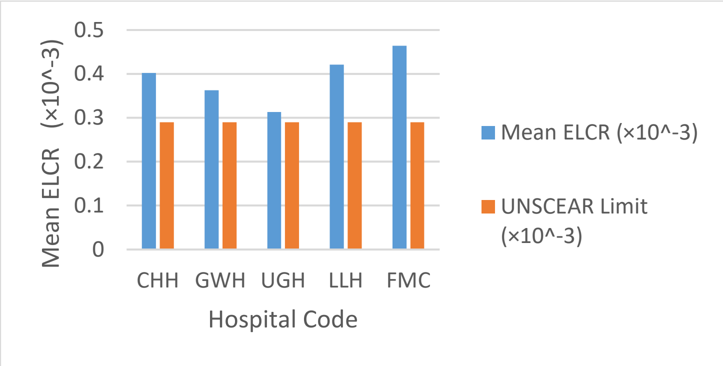


**Figure 3: Comparison of Mean Excess Lifetime Cancer Risk Across Hospitals with UNSCEAR Limit**

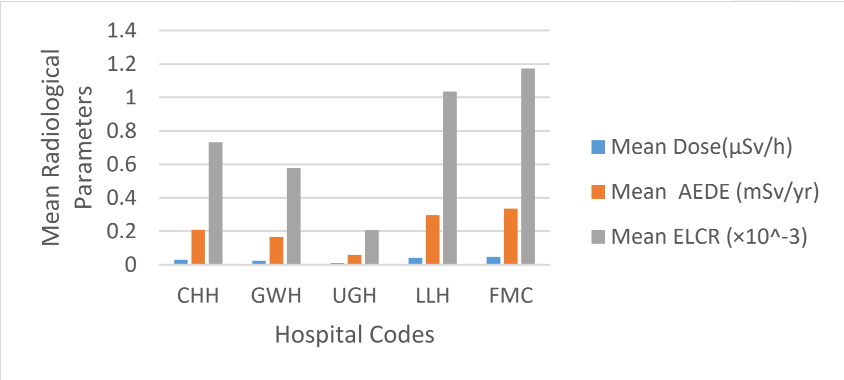


**Figure 4: Comparison of Mean Radiological Parameter in the Radiology department in the studied Hospitals**

### 3.2 Spatial Variation Across Functional Zones and Facilities

Table 3 presents the mean ADR, AEDE and ELCR for each functional zone across all five hospitals while Figure 5 shows the Comparison of the mean radiological parameters by functional zones. The highest mean ADR was observed in radiology departments (0.03036 µSv/h) which was 2.18 times higher than clinical zones (0.01392 µSv/h). Laboratory zones presented intermediate values (0.01612 µSv/h); 1.16 times higher than clinical zones.

**Table 3: Radiological Parameters by Functional Zone**

| Zone Type | N | Mean ±SD ADR (µSv/h) | Mean ±SD AEDE (mSv/yr) | Mean ±SD ELCR ($\times 10^{-3}$) | Relative to Baseline |
|---|---|---|---|---|---|
| **Radiology** | 5 | 0.03036 ± 0.01491 | 0.2127 ± 0.1045 | 0.744 ± 0.366 | 2.18× |
| **Laboratory** | 10 | 0.01612 ± 0.00504 | 0.1130 ± 0.0353 | 0.396 ± 0.124 | 1.16× |
| **Clinical** | 35 | 0.01392 ± 0.00504 | 0.0976 ± 0.0353 | 0.342 ± 0.124 | 1.00× (Baseline) |

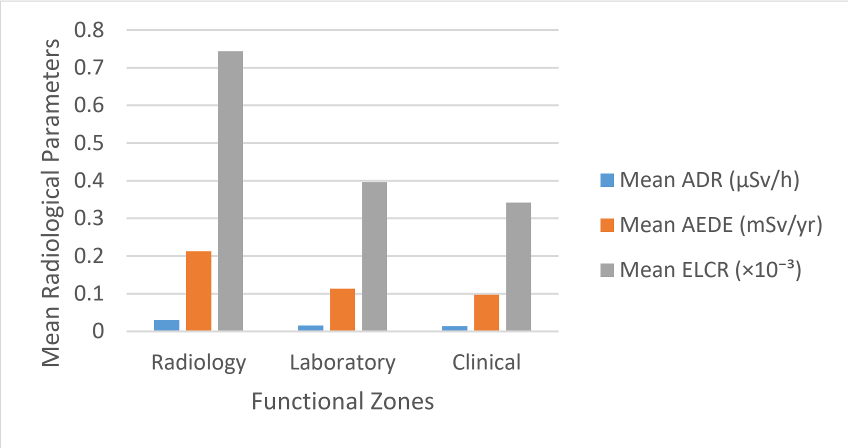


**Figure 5: Comparison of Mean Radiological Parameters by Functional Zone**

Radiology departments are expected to have the highest ambient dose rates (0.0084-0.0478 µSv/h) as these areas contain X-ray equipment and also have residual scattered radiation from previous exposures (Seeram & Brennan, 2016). The substantial differences between the facilities imply that the age of the equipment, the maintenance of the equipment, the integrity of the shielding, and the design of the room have a large effect on the residual radiation levels. This finding is in agreement with that of Ovwasa et al. (2023) who reported that some of the X-ray machines in Warri diagnostic centres were operating above safety thresholds due to poor maintenance and ageing components. Contour maps showing the spatial distribution of ambient radiation within each facility are shown in Figure 6. The maps visually identify radiation “hotspots” in radiology departments and the surrounding areas and can be a valuable tool for hospital administrators to visualize the spread of radiation and target interventions to areas of high exposure. The contour map of CHH (Figure 6) shows a clear radiation gradient with highest levels concentrated in the Imaging/Radiology department (0.0298 µSv/h). Elevated levels extend into adjacent areas such as the Laboratory (0.0252 µSv/h) and Surgery/Operating Theatre (0.0170 µSv/h). The lowest levels were recorded in the Emergency Unit (0.0092 µSv/h) and Psychiatric Unit (0.0104 µSv/h) which are located at greater distances from the radiology department. This spatial pattern indicates that shielding is present, but some radiation leakage from the radiology department into surrounding clinical zones is occurring. The ELCR at the radiology department ($0.731 \times 10^{-3}$) is higher than the global average of the UNSCEAR but lower than the ICRP upper limit.

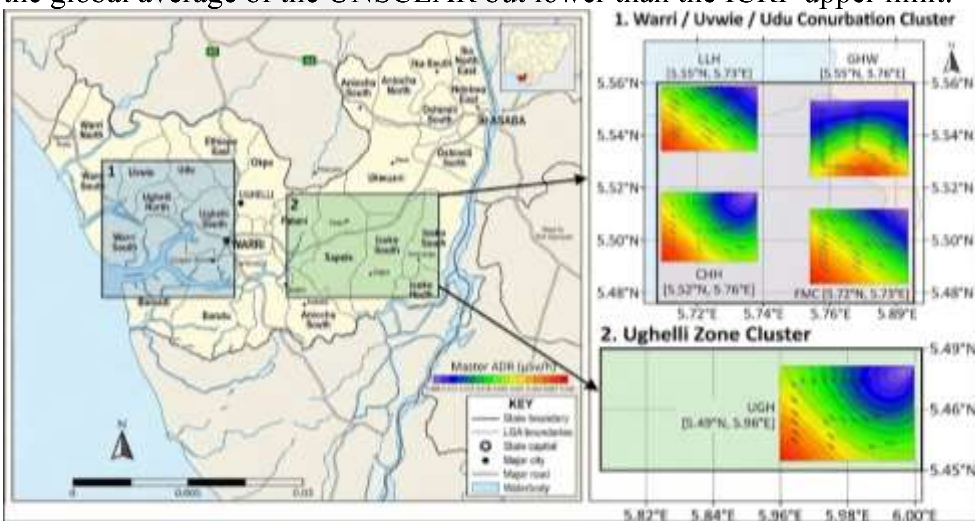


**Figure 6: Contour Map of Ambient Radiation Distribution at the Hospitals in the Study Area**

The contour map of GWH showed a similar pattern as CHH with Imaging/Radiology department having the highest levels (0.0236 µSv/h) followed by Operating Theatre (0.0184 µSv/h) and Laboratory (0.0172 µSv/h). Less steep radiation gradient than CHH indicating better containment of scattered radiation. The lowest levels were in the Emergency Unit (0.0096 µSv/h) and Psychiatric Unit (0.0098 µSv/h). The ELCR of radiology department ($0.579 \times 10^{-3}$) is higher than the global average risk by UNSCEAR, but lower than the upper limit by ICRP. The relatively flat distribution in the clinical areas (0.0134-0.0154 µSv/h) suggests proper shielding throughout the facility.
Of the five hospitals, UGH had the most uniform distribution of radiation in the contour map. The Radiology department had the lowest value (0.0084 µSv/h) similar to clinical zones, which was recorded by the Imaging/Radiology department. The highest levels were observed in Operating Theatre (0.0190 µSv/h) and Laboratory (0.0172 µSv/h). The Emergency Unit and Psychiatry had the lowest levels (0.0086 µSv/h and 0.0092 µSv/h, respectively). The ELCR at the radiology department ($0.206 \times 10^{-3}$) is below the UNSCEAR global average. This was the only facility where all locations were within the UNSCEAR global average. This exceptional performance shows modern equipment, perfect screening and optimal facility design. The contour map shows no distinct "hotspot," indicating effective containment of scattered. The LLH contour map shows a high radiation “hotspot” at the Imaging/Radiology department (0.0422 µSv/h); which is the second highest in all hospitals. Elevated levels are observed far into the adjacent areas, such as the Laboratory (0.0190 µSv/h), Operating Theatre (0.0204 µSv/h) and Emergency Unit (0.0140 µSv/h). Scattering of high radiation levels into adjacent clinical areas suggests the absence of shielding or room design. The ELCR in the radiology department ($1.035 \times 10^{-3}$) exceeds the upper acceptable limit of ICRP, indicating a non-negligible risk of cancer to workers occupationally exposed. The contour pattern exhibits a distinct gradient of radiation, with levels decreasing with distance from the radiology department, but the elevated baseline in adjacent areas indicates radiation leakage. The contour map of FMC is the highest radiation “hotspot” among the five hospitals, with the Imaging/Radiology department having the highest value (0.0478 µSv/h). Higher levels are also observed in the surrounding areas such as the Laboratory (0.0200 µSv/h), Operating Theatre (0.0234 µSv/h) and Emergency Unit (0.0154 µSv/h). The highest ELCR was found in the radiology department ($1.172 \times 10^{-3}$) which was the highest among all the locations surveyed and above the ICRP upper acceptable limit. The widespread elevated radiation levels indicate significant radiation leakage, which could be caused by poor shielding, outdated equipment or a large number of patients. The contour pattern shows a gradual decrease in radiation levels with distance, but the elevated baseline radiation levels seen throughout the facility (0.0106-0.0154 µSv/h in clinical zones) are higher than those found in other hospitals, indicating systemic elevation. The contour maps clearly indicate that the inadequately shielded facilities (LLH and FMC) have a widespread radiation from radiology departments into adjacent clinical zones. The ELCR values in these facilities were also above the upper acceptable limit of ICRP. On the other hand, the good shielding of CHH did not show any definite hotspot and all locations had ELCR values less than the global average of UNSCEAR. This spatial analysis provides strong evidence for the importance of shielding integrity in radiation protection and supports the ALARA principle’s focus on optimization through facility design (ICRP, 2007; Clement et al., 2021).

### 3.3 Organ-Specific Equivalent Doses

Table 4 presents the organ dose summary by tissue weighting factor from each of the facilities. The organ doses were associated with the tissue weighting factors of the ICRP (ICRP, 2007). The highest doses were found in organs with $w_T = 0.12$ (bone marrow, colon, lung, stomach, breast) (0.0107-0.0159 mSv/yr), followed by gonads ($w_T$ = 0.08;

0.0071-0.0106 mSv/yr) and organs with $w_T$ = 0.04 (bladder, oesophagus, liver, thyroid; 0.0036-0.0053 mSv/yr). This pattern is reflective of the relative radiosensitivity and cancer risk attributed to different tissues (Harrison et al., 2021).

**Table 5: Organ Dose Summary by Tissue Weighting Factor**

| Tissue Weighting Factor | Organs | Mean Dose Range (mSv/yr) |
|---|---|---|
| **0.12** | Bone marrow, colon, lung, stomach, breast | 0.0107-0.0159 |
| **0.08** | Gonads | 0.0071-0.0106 |
| **0.04** | Bladder, oesophagus, liver, thyroid | 0.0036-0.0053 |

These organ doses are substantially lower than those reported for diagnostic procedures. Abdomen and pelvis CT Ovary doses: 11.15-39.2 mGy Uterus doses: 12.10-43.05 mGy (Obed et al., 2016) Eye lens doses with a ratio of SOAD/ED = 36.5 were obtained from CT examinations by Maidamma et al. (2026). Skin doses of 0.275-0.717 mGy for chest X-ray examinations were reported by Onwukwe (2025). These comparisons show the large difference between occupational/environmental exposure and patient medical exposure.
However, cumulative organ doses for healthcare workers over 30-year careers in facilities with increased ambient levels may reach or exceed ICRP annual limits for specific organs if adequate shielding and protective measures are not maintained. This result supports the use of personal protective equipment (lead aprons, thyroid shields, and lead glasses) and regular dosimetry for occupationally exposed workers (Clement et al., 2021; Lopes et al., 2025).

### 3.3 Statistical Analysis

Table 5 presents the One-Way ANOVA Summary (Hospitals Comparison) and Table 7 shows the independent t-Test results comparing the ADR between the radiology and clinical and Laboratory and clinical zones of the studied hospitals.

**Table 5: One-Way ANOVA Summary (Hospitals Comparison)**

| Source | SS | df | MS | F | p-value |
|---|---|---|---|---|---|
| **Between Hospitals** | 0.000286 | 4 | 0.0000715 | 1.186 | 0.329 |
| **Within Hospitals** | 0.002713 | 45 | 0.0000603 | - | - |
| **Total** | 0.002999 | 49 | - | - | - |

There was no significant difference in mean ADR across hospitals (p=0.329) suggesting comparable baseline environments across facilities. This supports the generalizability of findings across the five hospitals and suggests that baseline radiation environments are similar despite different types of facilities (public vs. private) and locations.
As presented in Table 6, radiology departments had significantly higher ADR than clinical zones (p<0.0001), confirming these as the main sources of increased ambient radiation and supporting ongoing focus on radiology departments for radiation safety interventions. This finding is consistent with previous studies that identified radiology areas as high-priority areas for radiation protection (Orlunta & Sokari, 2023; Ukerun-Akpesiri et al., 2023).
The mean ADR was slightly higher in laboratory zones (0.01612 µSv/h) than in clinical zones (0.01392 µSv/h); however, the difference was not statistically significant (p = 0.225). The finding contributes to the growing evidence that routine radiation monitoring programmes may overlook laboratory areas. Previous radiation surveys in Nigeria have largely focused on radiology departments and this may underestimate the exposure risks for laboratory staff (Eyisi-Enuka et al., 2021; Ovwasa et al., 2023). The uniform pattern of marginally elevated readings across all five facilities points to a need for caution and suggests the need for routine monitoring to be extended to laboratory zones.

**Table 6: Independent t-Test Results**

| Comparison | t | df | p-value | Significance |
|---|---|---|---|---|
| **Radiology vs. Clinical** | 4.92 | 38 | <0.0001 | Significant |
| **Laboratory vs. Clinical** | 1.23 | 43 | 0.225 | Not significant |

## 4. Conclusion

The study successfully established a comprehensive baseline data set on ambient radiation levels and associated health risks in specialist hospitals in Delta State, Nigeria. The results show that all five hospitals are within internationally accepted safety standards for public exposure to radiation. But the systematic dose above natural background levels, combined with high excess lifetime cancer risks in two radiology departments, reveals opportunities for further optimization under the ALARA principle. The spatial analysis by contour mapping has been particularly useful in identifying radiation hot-spots and emphasizing the importance of the integrity of shielding to contain the scattered radiation. The study highlights that regulatory compliance alone is not enough to ensure an optimal radiation protection, and facility-specific interventions, routine monitoring and continuous training of the staff are important to reduce the stochastic health risk. The findings provide an evidence-based basis to strengthen radiation safety policies, promote occupational health and improve sustainable healthcare delivery in the region.

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