*Research Article* *Open Access*

**Journal of Clinical Oncology & Advanced Therapy**

**ISSN: 3070-3786**

***DOI:*** doi.org/10.63721/26JCOAT0132

# *Evaluating Environmental Implications of Ionizing Radiation Dosimetry at Selected Hospitals in Benue South Senatorial District, Nigeria*

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***Citation:****Elijah Ebibi Onwoke, Andrew Ichoja, Onah Emmanuel Onah, Samuel I Peter, Iortile Joseph Teryima, et al. (2026) Evaluating Environmental Implications of Ionizing Radiation Dosimetry at Selected Hospitals in Benue South Senatorial District, Nigeria. J of Clin Onco & Adv Thpy 2(4), 1-10. WMJ/JCOAT-132*

## *Abstract*

*There is an urgent need for comprehensive radiation monitoring in Nigeria's healthcare facilities due to the rapid increase in ionizing medical technologies. It critiques existing studies in developing countries for being one-dimensional (focusing solely on either indoor occupational or outdoor background exposure) and notes that the influence of building structures on radiation distribution is understudied in Sub-Saharan Africa. Finally, it presents the Benue South Senatorial District as an ideal, yet unexplored, location for an integrated dosimetric assessment, given its expanding healthcare infrastructure. This study aimed to undertake a comprehensive evaluation of environmental ionizing radiation dosimetry in selected hospitals in Benue South Senatorial District, Nigeria. A cross-sectional environmental dosimetric survey was executed across two purposively selected hospitals spanning the two Local Government Areas of Benue South District—Otukpo and Okpokwu. An in-situ measurement using a calibrated RAD-35 radiometer (SN: 260310122, Shandong Vict Equipment Ltd) was used to determine the radiation level for both indoor and outdoor. A total of 280 sampling locations were surveyed across the two Local Government Areas. The average values for indoor and outdoor BIR were taken at each of the wards within the hospital, and the measurements were used to evaluate the radiological health hazards and radiation effective doses to different body organs. The results showed that the total Dose Rates, the Total Annual Equivalent Dose, total Annual Effective Dose Equivalent and the total Excess Lifetime Cancer Risk are: 0.068±0.049 (µSv/h) and 0.077±0.016 (µSv/h), 0.478±0.340 mSv/y and 0.045±0.016 mSv/y, 0.335±0.238 mSv/y and 0.083±0.003 mSv/y, 1.732±0.453 and 0.045±0.054 respectively for the two hospitals. Organ dosimetry revealed testes received the highest dose of 0.701 mSv/y, while the liver received the lowest dose of 0.395 mSv/y across the hospitals. The finding indicated that the Annual Effective Dose Equivalents remained within ICRP's permissible limits of 1.0 mSv/y for general public exposure, and organ-specific effective doses were below recommended limits. However, the calculated Excess Lifetime Cancer Risk (indoors and outdoors) exceeded the world permissible limit of $0.29\times10^{-3}$. While this elevated value does not pose an immediate radiological health threat, continuous exposure over a long time may present a significant risk to the occupational workers and population.*

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**Submitted:** 04.08.2026 **Accepted**: 07.08.2026 **Published**: 18.08.2026

**Keywords**: Background ionizing radiation, Equivalent Dose, Effective Dose and Excess Lifetime Cancer Risk

## Introduction

Exposure to radiation from the environment is one of the inescapable aspects of human existence. The radiation may be from natural sources, such as the soil's radionuclides, cosmic radiation due to ionization of gases in the atmosphere, radon gas, granite rock, water, sediments, or artificial sources from X-ray machines, building materials, radioactive waste from nuclear reactors, the fallout from nuclear weapons testing, and nuclear accidents. The amount of radiation emitted in the environment varies depending on geographical locations. Ionizing and non-ionizing radiation are the two types of radiation. Ionizing radiation is a type of radiation that can produce ions, disrupting life processes by causing ionization in matter when irradiated, which is more detrimental to the human body than non-ionizing radiation [1]. Non-ionizing radiation, on the other hand, does not create ions in irradiated matter, even though it may harm human health in different ways [1]. Ionizing radiation has recently caught the attention of the general public mostly due to the fact that it is widely used in medical diagnosis or therapy and it has the capacity to break atoms and create positive ions and negative electrons, which potentially cause biological damage to humans when exposed to it. X-rays, gamma rays, alpha particles, beta particles, neutrons, and cosmic rays are examples of ionizing radiation. Medical radiation has contributed largely among all anthropogenic ionizing radiation, and its contribution to the total exposure is increasing [2]. Globally, medical radiation contributes 20% of the total annual effective dose, and its contribution is more than 50% of its share to total annual exposure for the US general public [3].

Although ionizing radiation is harmful, people have greatly benefited from its uses in the healthcare industry ever since its discovery. Ionizing radiation is helpful in the medical sector for performing diagnostic imaging and therapeutic procedures, which provide vital information about patients' health to medical doctors to help them ensure that proper medical treatment and attention are given to patients when the need arises [4]. The procedures, however, do involve many individuals being exposed to radiological dangers, particularly if the effective dose is greater than the recommended allowed dose from radiation safety regulatory bodies. Over the years, both indoor and outdoor background radiation have become a public health issue. Therefore, it is crucial to determine its level in strategic areas of our hospitals or radiological centers to monitor and adhere to international standards.

Recently, several studies have been conducted in Nigeria to determine the levels of natural background radiation in hospitals, evaluated and reported on the environmental measurement of indoor and outdoor ionizing radiation in the University of Mkar[5]. The majority of the results from the analyzed radioactive parameters were found to be within the permissible limits and did not pose any immediate radiological health problems to the community, but continuous monitoring of ionizing radiation levels in the study location was recommended. Assessment of background ionizing radiation conducted at several laboratories in Plateau State University Bokkos by recorded high values of radiation dose equivalent for indoor and outdoor radiation greater than 0.24 mSv/y, proposed by the United Nations Committee on Effects of Atomic Radiation (UNCEAR).

The background radiation dose level of 29 rooms at Queen Amina Hostel, Ahmadu Bello University, Zaria, was measured by [6]. Their results disclosed a radiation dose level range of 0.13 nGy/h to 0.43 nGy/h and 0.54 nGy/h to 1.72 nGy/y for indoor and outdoor radiation, respectively [7]. In Ogwashi-Nku, Delta

State, the indoor and outdoor radiation profile was studied using an inspector survey meter. Their results revealed that the values for the annual dose rate and excess life cancer risks were lower than the 1.0 mSv/y safe limits prescribed by the International Commission on Radiological Protection (ICRP). The dosimetric study of natural background ionizing radiation and impact assessment on public health was reviewed by to monitor the direct and indirect exposure of people to ionizing radiation [8]. It was observed that states like Oyo, Kano, Niger, and Sokoto have values of radiation dose rates greater than the acceptable limits recommended by the WHO [9-12]. Hospitals and other medical institutes have been identified as high-risk zones for background ionizing radiation exposure. [13], studied the background ionizing radiation of the Skane Radiodiagnostic Centre, Jos Plateau State, Nigeria. They found that the background ionizing radiation indoors and outdoors was 1.063 mSv/y and 1.848 mSv/y, respectively, while the indoor and outdoor background ionization for Plateau Specialist Hospital was 2.444 mSv/y and 2.002 mSv/y, respectively. The results of the investigation carried out by [14], showed that the background ionizing radiation at the Braithwaite Memorial Specialist Hospital, Port Harcourt, ranged from 0.14±0.01 to 0.16±0.01µSv/h with the mean value of 0.146 µSv/h for the indoor measurement and 0.10±0.02 to 0.17±0.01µSv/h with the mean value of 0.1413±0.02 µSv/h for the outdoor measurement respectively.

Thus, this study aims to assess and determine the health implications of background ionizing radiation within the indoor and outdoor environment of selected hospitals in Benue South Senatorial District, Nigeria. The outcome of this research will mitigate long-term exposure of the public and occupational workers to these radiations that may lead to radiation-induced health hazards such as erythema, skin cancer, genetic mutation, and sterility.

## Materials and Method

### Study Area

Benue State is one of the thirty-six (36) states in Nigeria. It is geographically located in North–Central Nigeria with three (3) senatorial districts, namely Benue West, North, and South senatorial areas. The state lies between latitudes 6°30°North and 8°15°North and longitudes 7°30 ′ East and 10°00°North. According to the national population census of 1991 and 2006, Benue State has a land mass of approximately 34,059 km2 and a population of about 2,780,398 and 4,253,541 (Census 2006 and 2009), respectively. This present research took place in Benue State senatorial district, Nigeria. Hospitals were selected from chosen local government areas of Otukpo LGA (Federal University of Health Sciences Teaching Hospital, Otukpo, FUHSTHO) and Okpukwu LGA (General Hospital, Okpoga) for the study, as depicted in Figure 1. The local dwellers of the study sites are predominantly farmers, and the large population size of the inhabitants frequently visit the hospitals for their medical examinations, and the staff who spend a minimum of 8 hours daily in the environment carrying out their routine medical operations.


### Samples Collection and Preparation

Background ionizing radiation within the indoor and outdoor environment at the nine general hospitals in Benue South senatorial district, Nigeria, was measured using a hand-held automated radiation detector, a 1m high table, a Global Positioning System (GPS) for detection of the actual sampling point, and a pen and a notebook for accurate recording purposes. Laboratory analysis and an In-situ evaluation of ionizing radiation are the main two approaches to execute the study. In the present study, the In-situ approach was adopted so that the original environmental characteristics of the samples would not be altered. A total number of 140 points were measured and analyzed across the two study stations. Sampling points of interest include male and female wards, children's departments, theatre, maternity, outpatient sections, and Consultant office sections, respectively.

A well-calibrated radiation meter, RAD-35 (SN: 260310122, Shandong Vict Equipment LTD) were used for the radiation dose measurement. This detector has a long history of excellent radiation measurement with a wide range of useful applications. It consists of an inbuilt high-sensitive energy-compensated Geiger-Muller tube and is specifically designed for accurate measurement of low-level radiation such as alpha (α), beta (β), gamma (γ), and X-rays and radiation dose equivalent. Following the recommended radiation measurement procedure, the Radiation meter RAD-35 was held at a distance of 1.0 m above the ground to record the reading when the meter was switched on and positioned 30 cm away from a particular measured location. For accuracy and avoidance of error, at each measurement point, five sets of readings were taken at every four different locations, and the mean values were calculated and analyzed for the indoor and outdoor environment. A total of 280 sampling locations were surveyed across the two Local Government Areas –that is, every 140 locations for indoor and outdoor (male wards, female wards, children wards, theatre, outpatient wards, consultant offices and maternity wards). Based on the manufacturer's recommendation for maximum response of the instrument, the reading will be taken at noon time between 1200hrs and 1600hrs [15].

## Samples Analysis

### Radiation Health Risk Impact Assessment:

Different known radiation health hazard indices analysis is been use in radiation studies to arrive at a better and safer conclusion on the health status of a radiated or irradiated person and environment [16].

### Equivalent Dose:

The indoor and outdoor data obtained from the in-situ measurement for the two government areas within the study area were processed for mean value by adding up all the raw data obtained for each location and dividing by the number of data taken to get the mean value for the location.

### Annual Effective Dose Rate (AEDR)

This is the total dose received by an individual who is exposed to ionizing radiation. It is used as a protection level dosimetry for stochastic prediction. The mean equivalent dose rate in μSv/h obtained from the processing of the in-situ measurement was used to calculate the corresponding indoor and outdoor annual equivalent dose rate in $mSvy^{-1}$ using the radiological relation given by (James et al., 2020).

$$\mathrm{IAEDR}(\mathrm{mSvy}^{-1}) = \alpha(\mu\mathrm{Svhr}^{-1}) \times 8760(\mathrm{hryr}^{-1}) \times 0.8 \times 10^{-3} \tag{1}$$

$$\mathrm{OAEDR}(\mathrm{mSvy}^{-1}) = \beta(\mu\mathrm{Svhr}^{-1}) \times 8760(\mathrm{hryr}^{-1}) \times 0.2 \times 10^{-3} \tag{2}$$

Where α and β are the indoor and outdoor meter readings

Annual Effective Dose Equivalent (AEDE)

Radiation absorbed dose is a measure of the amount of energy absorbed per unit mass. It quantifies the radiation energy that might be absorbed by a potentially exposed individual as a result of a specific exposure. For whole body exposure, the quantity effective dose equivalent is used to measure the whole body absorbed dose. The annual effective dose equivalent (AEDE) is used in radiation assessment and protection to quantify the whole body absorbed dose per year. To estimate the AEDE, the conversion factor (0.7 Sv/Gy) from absorbed dose rate in air in nGy/h to effective dose rate in mSv/y is used with indoor occupancy factor of 0.8 and outdoor occupancy factor of 0.2. The AEDE was calculated in indoor and outdoor environments using the following formulae (UNSCEAR, 2000) [17].

AEDE (Indoor) (mSv/y) = Din (nGy/h) x 8760 (h) x 0.8 x 0.7 Sv/Gy x 10-3 (4)

$$\mathrm{AEDE}(\mathrm{Indoor})(\mathrm{mSvy}^{-1}) = \mathrm{D}_{\mathrm{in}}(\mathrm{nGyh}^{-1}) \times 8760(\mathrm{hryr}^{-1}) \times 0.8 \times 0.7 \times 10^{-3} \tag{3}$$

$$\mathrm{AEDE}(\mathrm{outdoor})(\mathrm{mSvy}^{-1}) = \mathrm{D}_{\mathrm{out}}(\mathrm{nGyh}^{-1}) \times 8760(\mathrm{hryr}^{-1}) \times 0.8 \times 0.7 \times 10^{-3} \tag{4}$$

Where $D_{in}(nGyh^{-1}) = \frac{IAEDR\times10^{-3}}{Q}$ and Q = Quality factor

Where $D_{out}(nGyh^{-1}) = \frac{OAEDR\times10^{-3}}{Q}$ and Q = Quality factor

## Excess Lifetime Cancer Risk (ELCR)

This gives the probability of developing cancer over a lifetime at a given exposure level. The ELCR for indoor and outdoor had been calculated using the following equation [18].

$$ELCR_{in} = AEDE_{in} \times DL \times RF \quad (5)$$

$$ELCR_{out} = AEDE_{out} \times DL \times RF \quad (6)$$

Where DL and RF are the average duration of life (70 years average) and risk factor (Sv), that is, fatal cancer risk per Sievert, respectively. For stochastic effects, the ICRP 106 used a value of RF = 0.05 for the public.

## Effective dose rate (Dorgan) to Different Body Organs and Tissues

The effective dose to organs (Dorgan) estimates the amount of radiation dose intake to various body organs and tissues. The effective dose rate delivered to a particular organ can be calculated for indoor and outdoor using the following relation [18]; [8].

$$D_{Organ}(Indoor)(mSvyr^{-1}) = AEDE_{in} \times F \quad (7)$$

$$D_{Organ}(outdoor)(mSvyr^{-1}) = AEDE_{out} \times F \quad (8)$$

$$Organ\ Cancer\ Risks_{indoor} = D_{Organ}(Indoor)(mSvyr^{-1}) \times DL \times F \quad (9)$$

$$Organ\ Cancer\ Risks_{outdoor} = D_{Organ}(outdoor)(mSvyr^{-1}) \times DL \times F \quad (10)$$

Where F and O are the conversion factors of organ dose from air dose, and O is the occupancy factor 0.2 (indoor) and 0.8 (outdoor).

## Results and Discussion

Equivalent Dose: The indoor and outdoor data obtained from the in-situ measurement for the two hospitals within the study area were processed for mean value by adding up all the raw data obtained for each location and dividing by the number of data taken to get the mean value for the location. The result is shown in Tables 1-3. Annual Equivalent Dose: The Annual Equivalent Dose rate for the two hospital zones is shown in Tables 1-2. A summary of the Annual Equivalent Dose rate (Table 3) shows that the Indoor dose rate ranges from 0.0.54±0.048 µSv/h to 0.082±0.049 µSv/h with a mean of 0.068±0.049 µSv/h, and the Outdoor dose rate ranges from 0.046±0.017 µSv/h to 0.054±0.014µSv/h with a mean of 0.077±0.016 µSv/h. These values are below the standard background radiation of 0.133 µSv/h.

**Table1:** Measured indoor and outdoor Dose Rate and Evaluated hazard indices in FUHSTHO

| S/N | Location code | AIDR | AODR | AEDRI | AEDRO | AEDEI | AEDEO | ELCRI | ELCRO |
|---|---|---|---|---|---|---|---|---|---|
| | | (µSv/hr) | (µS/hr) | (mSv/y) | (mSv/y) | (mSv/y) | (mSv/y) | (*10^-3) | (*10^-3) |
| 1 | MW | 0.159 | 0.039 | 1.114 | 0.068 | 0.781 | 0.012 | 2.114 | 0.082 |
| 2 | FW | 0.054 | 0.079 | 0.378 | 0.138 | 0.265 | 0.024 | 1.9 05 | 0.119 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| 3 | CW | 0.026 | 0.032 | 0.182 | 0.056 | 0.129 | 0.01 | 2.489 | 0.106 |
| 4 | TH | 0.025 | 0.059 | 0.175 | 0.103 | 0.123 | 0.018 | 2.183 | 0.088 |
| 5 | OPD | 0.031 | 0.036 | 0.217 | 0.063 | 0.152 | 0.011 | 1.853 | 0.061 |
| 6 | CO | 0.031 | 0.039 | 0.217 | 0.068 | 0.152 | 0.012 | 2.221 | 0.045 |
| 7 | Mw | 0.053 | 0.038 | 0.371 | 0.067 | 0.26 | 0.012 | 1.63 | 0.082 |
| | Mean Value | 0.054± 0.048 | 0.046± 0.017 | 0.379± 0.335 | 0.080± 0.029 | 0.266± 0.235 | 0.014± 0.005 | 2.052± 0.283 | 0.083± 0.025 |

AIDR = Average Indoor Dose Rate, AODR = Average outdoor Dose Rate, AEDI = Annual Equivalent Dose (Indoor); AEDO = Annual Equivalent Dose (Outdoor), AEDEI = Annual Effective Dose Equivalent indoor; AEDEO = Annual Effective Dose Equivalent outdoor; ELCRI = Excess Lifetime Cancer Risk indoor, ELCRO = Excess Lifetime Cancer Risk outdoor, MW= Male ward, FW= Female ward, CW= Children ward, TH= Theatre, OPD= Outpatient ward, CO = Consultant office and Mw = maternity ward.

**Table 2:** Measured indoor and outdoor Dose Rate and Evaluated hazard indices in Okpoga General Hospital

| S/N | Location code | AIDR | AODR | AEDRI | AEDRO | AEDEI | AEDEO | ELCRI | ELCRO |
|---|---|---|---|---|---|---|---|---|---|
| | | (µSv/hr) | (µS/h) | (mSv/y) | (mSv/y) | (mSv/y) | (mSv/y) | (*10^-3) | (*10^-3) |
| 1 | MW | 0.068 | 0.064 | 0.477 | 0.011 | 0.334 | 0.002 | 1.169 | 0.007 |
| 2 | FW | 0.043 | 0.053 | 0.301 | 0.009 | 0.211 | 0.002 | 0.739 | 0.006 |
| 3 | CW | 0.1 | 0.074 | 0.701 | 0.013 | 0.491 | 0.002 | 1.719 | 0.008 |
| 4 | TH | 0.087 | 0.066 | 0.61 | 0.011 | 0.427 | 0.002 | 1.496 | 0.007 |
| 5 | OPD | 0.182 | 0.039 | 1.276 | 0.007 | 0.894 | 0.001 | 3.128 | 0.004 |
| 6 | CO | 0.049 | 0.041 | 0.343 | 0.007 | 0.241 | 0.001 | 0.842 | 0.004 |
| 7 | Mw | 0.046 | 0.042 | 0.322 | 0.007 | 0.226 | 0.001 | 0.791 | 0.004 |
| | Mean Value | 0.082± 0.049 | 0.054± 0.014 | 0.576± 0.344 | 0.009± 0.002 | 0.403± 0.241 | 0.002± 0.000 | 1.412± 0.844 | 0.006± 0.001 |

**Table 3**: Summary of Measured Indoor and Outdoor Dose Rate and Evaluated Hazard Indices for Two Hospitals

| | AIDR | AODR | AEDRI | AEDRO | AEDEI | AEDEO | ELCRI | ELCRO | Total |
|---|---|---|---|---|---|---|---|---|---|
| **LOCATION** | (µSv/hr) | (µS/hr) | (mSv/yr) | (mSv/yr) | (mSv/yr) | (mSv/yr) | (*10^-3) | (*10^-3) | ECLR |
| **FUHST-HO** | 0.054± 0.048 | 0.046± 0.017 | 0.379± 0.335 | 0.080± 0.029 | 0.266± 0.235 | 0.014± 0.005 | 2.052 | 0.083 | 2.135 |
| **OKPOGA General Hospital** | 0.082± 0.049 | 0.054± 0.014 | 0.576± 344 | 0.009± 0.002 | 0.403± 0.241 | 0.002± 0.000 | 1.412 | 0.006 | 1.418 |
| **Mean Values** | 0.068± 0.049 | 0.077± 0.016 | 0.478± 0.340 | 0.045± 0.016 | 0.335± 0.238 | 0.008± 0.003 | 1.732± 0.453 | 0.045± 0.054 | 1.777± 0.507 |

Annual Effective Dose Equivalent (AEDE): The AEDE for the two hospitals is shown in Tables 1-2, and a comparison with the internationally recommended limit is shown in Figure 1. A summary of the AEDE (Table 3) shows that the Indoor AEDE ranges from 0.266±0.235 mSv/y to 0.403±0.241 mSv/y with a mean of 0.335±0.238 mSv/y and Outdoor AEDE ranges from 0.002±0.000 mSv/y to 0.014±0.005 mSv/y with a mean of 0.008±0.003 mSv/y. These values are lower than the ICRP permissible safety limits of 1.0 mSv/y for the public and 20 mSv/y for occupationally exposed workers. This indicates that the studied areas are in good agreement with the permissible limit and do not constitute any immediate radiological health effect on the workers and the general public due to background ionizing radiation (BIR) exposure. However, periodic assessment of activity concentration of natural radionuclides and BIR levels in the study area should be carried out in order to ensure that exposure to radiation within the areas is kept as low as reasonably achievable.

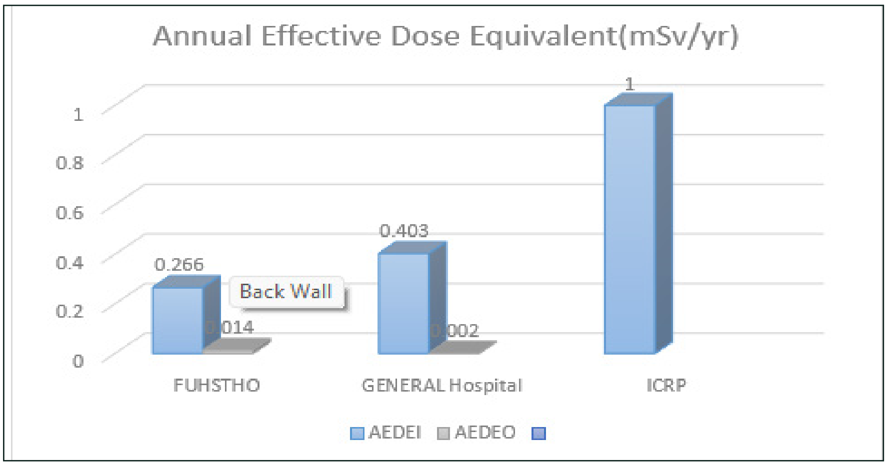


**Figure 1**: Annual Effective Dose Equivalent for Indoor and Outdoor for the two Hospitals

Excess Lifetime Cancer Risk (ELCR): The excess lifetime cancer risk is used in radiation protection assessment to predict the probability of an individual developing cancer over his lifetime due to low radiation dose exposure, if it will occur at all. The ELCR for the two hospitals is shown in shown in (Tables1-2) and a comparison with the world average is shown in Figure 2. A summary of the ELCR (Table 3) shows that the Indoor ELCR ranges from 1.412 x $10^{-3}$ to 2.052 x $10^{-3}$ with a mean of 1.732 x$10^{-3}$ which is 1.49 times higher than the world's average of 1.16 x $10^{-3}$ [19]. While, the Outdoor ELCR ranges from 0.006 x $10^{-3}$ to 0.083 x $10^{-3}$, with a mean of 0.045 x $10^{-3}$, which is 0.16 times higher than the world's average of 0.29 x $10^{-3}$ [20]. The total (ELCR) ranges from 1.418 X $10^{-3}$ to 2.135 x $10^{-3}$ with a mean of 1.778 x $10^{-3}$, which is 1.23 times higher than the world's average of 1.45 x $10^{-3}$ [19]. These low values for excess lifetime cancer risk indicate that the tendency of cancer development among occupational workers and the public who intend to spend their lifetime in the area is very low. The ELCR values reported in this study are lower than those reported for industrial areas of Warri and Effurun, Delta State, Nigeria [20], and also lower than the values from Emene Industrial Layout, Enugu , highly populated motor parks in Enugu State, Nigeria [21]. It is also lower than those for the salt lake environment of Okposi Okwu and Uburu of Ebonyi State, Nigeria [22] and river sediments from Northern Pakistan [19].

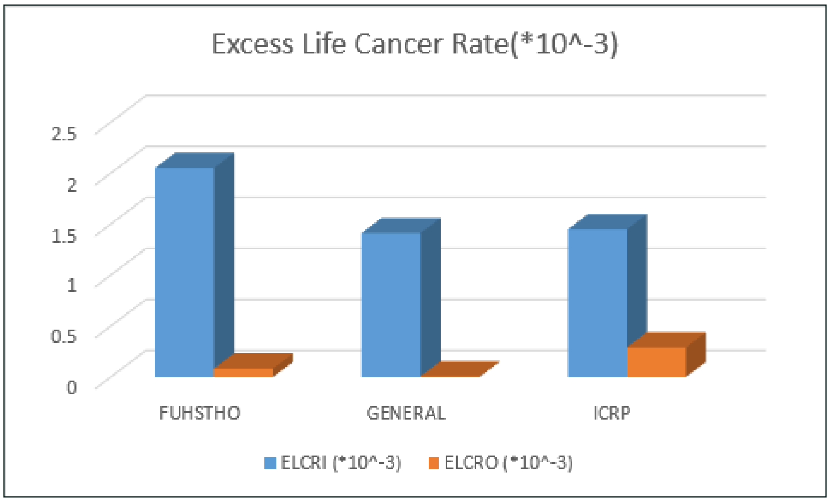


**Figure 2**: Excess Lifetime Cancer Risk for Indoor and Outdoor for the Two Hospitals in comparison with the permissible safety limit.

Effective dose rate (Dorgan) to different body organs and tissues: The result of the effective dose rate delivered to the different organs is presented in Figure 3, with the F values for Lungs, Ovaries, Bone marrow, Testes, Kidneys, Liver and Whole body as 0.64, 0.58, 0.69, 0.82, 0.62, 0.46 and 0.68 respectively, obtained from ICRP [2007]. The estimated average Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver and whole body due to radiation exposure and inhalation in the study area are 0.552, 0.500, 0.596, 0.701, 0.534, 0.395, 0.587 for indoor and 0.006, 0.006, 0.006, 0.007, 0.006, 0.004, 0.011 for outdoor respectively. These results are all below the international permissible limits of 1.0 mSv/y, which further buttresses that the radiation levels do not constitute any immediate health risk to health workers and the general public of the study area [21]. From the results, it is concluded that the testes and liver have the highest and lowest sensitivity to radiation, respectively, for indoor and outdoor. The relatively higher dose to the testes and low dose intake to the liver is justifiable from food nutrient absorption rate [24]. Similar conclusions have also been made by [18,20,21].

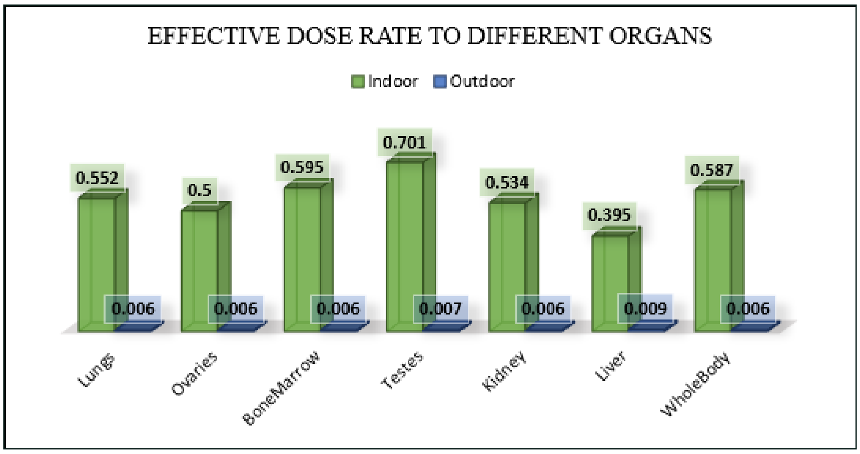


**Figure 3**: Effective Dose Rate to different Organs/Tissue (mSv/yr) for Two Hospitals

## Conclusion

A radiation meter RAD-35 was used to take indoor and outdoor measurements of background ionizing radiation levels at two hospitals within Benue South Senatorial District. The measurements were taken at four different locations across the hospitals. The analysis found that the mean equivalent dose rate levels are within the International Commission on Radiological Protection's standard acceptable limits (ICRP). The study showed that the mean equivalent dose rate levels in all the selected hospitals are within the standard permissible limits set by the International Commission on Radiological Protection. The mean indoor and outdoor annual effective dose equivalent for all the selected hospitals is within ICRP and UNSCEAR recommended permissible limits of 1.00 mSvy-1 for the general public [23,24].

The ionizing radiation exposure level in two selected hospitals across Benue South Senatorial district, Nigeria was carried out to determine: the indoor and outdoor ambient ionizing radiation doses in those hospitals, the annual effective dose resulting from exposure to this radiation, and then to determine the health hazards posed to the patient and occupational workers. The results showed that the mean equivalent dose rate levels in all the selected hospitals are within the standard permissible limits set by the International Commission on Radiological Protection. The mean indoor and outdoor annual effective dose equivalent for all the selected hospitals is within ICRP and UNSCEAR recommended permissible limits of 1.00 $mSvy^{-1}$ for the general public [23,24]. In the selected hospitals, the estimated Dorgan values for the lungs, ovaries, bone marrow, testes, kidney, liver, and whole-body due to radiation exposure and inhalation are all within the worldwide acceptable limits of 1.0 mSv annually. Hence, the selected hospitals are radiologically safe. However, we recommend that regular monitoring of activity concentration of natural radionuclides and BIR levels in the study area should be carried out to maintain the radiation level to as low as reasonably achievable.

## Acknowledgment

The authors are thankful to the management of Federal University of Health Sciences, Otukpo, and the Tertiary Education Trust Fund (TETFUND for their support, and the Heads of the hospitals for their permission to use their facilities to carry out this research.

## Declaration of Competing Interest

The authors declare that there is no competing financial interest or personal relationship to influence the present work.

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