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Original Article

Assessment of the Effects of X-Ray Leakage Exposure in Some Selected Teaching Hospitals in South Western Nigeria

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ABSTRACT

Leakage and scattering of X-rays through structural openings such as windows and doors during imaging procedures may lead to unintended exposure, increasing the risk of cancer, tissue and organ damage, and genetic mutations. Radiology personnel are particularly susceptible to these hazards, underscoring the need for continuous monitoring and evaluation of occupational radiation levels. This study aimed to quantify radiation exposure within X-ray rooms and adjoining areas in four selected teaching hospitals: LAUTECH Teaching Hospital (LTH), BOWEN Teaching Hospital (BTH), UNIOSUN Teaching Hospital (UTH), and UNIMED Teaching Hospital (UNIMEDTH). In-situ measurements were conducted using a handheld Radiation Alert Monitor at three standardized locations; the X-ray room, cubicle corridor, and waiting area at a height of 1.2 m, representing the approximate level of vital organs in adults. The estimated annual effective dose equivalent (AEDE) across the hospitals ranged from 0.73 ± 0.13 mSv/yr to 1.45 ± 0.32 mSv/yr, all within the International Commission on Radiological Protection (ICRP) occupational exposure limit of 20 mSv/yr. Radiation distribution patterns in UNIMEDTH, UTH, and BTH indicated effective structural shielding, whereas LTH exhibited significantly elevated exposure levels beside and behind the X-ray room (1.261 and 1.260 mSv/yr, respectively), suggesting potential shielding deficiencies. Overall, the findings show that although measured dose rates comply with international safety standards, localized areas of increased exposure highlight the need for improved shielding and stricter adherence to radiation protection practices. These results provide a vital baseline for enhancing occupational radiation safety and guiding structural optimization within medical imaging environments.

Keywords: Environmental radiation, occupational exposure, X-ray leakage, absorbed dose rate, annual effective dose equivalent (AEDE), medical imaging safety

INTRODUCTION

X-ray imaging is an essential component of modern medical diagnosis, with modalities such as radiography, fluoroscopy, and computed tomography widely used to visualize internal anatomical structures ((NIBIB, 2022). These techniques rely on ionizing radiation, which, although beneficial when properly controlled, can pose significant health risks under conditions of excessive or unintended exposure (Najjar, 2023). Ensuring radiation safety is therefore a fundamental requirement in clinical environments where healthcare personnel work in close proximity to X-ray producing equipment. A key source of avoidable occupational exposure is X-ray leakage and scattered radiation, which may escape through inadequately shielded walls, doors, windows, or ageing equipment in radiology suites (WHO, 2020). Such leakage can contribute to cumulative radiation doses among radiology staff, especially in facilities with inadequate structural shielding, limited monitoring programs, or high patient throughput. These challenges are more pronounced in many low- and middle-income countries (Ali and Chen, 2021), where periodic safety audits and infrastructural upgrades may be insufficiently implemented. Although several studies have examined patient doses and general occupational exposure trends within isolated institutions in Nigeria, there is limited empirical evidence on actual leakage radiation levels across multiple teaching hospitals, particularly in South-Western Nigeria. This lack of comprehensive assessment restricts the development of consistent radiation-protection protocols and prevents

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institutions from identifying potential lapses in shielding or facility design. This study addresses this gap by measuring absorbed dose rates around the radiology departments of selected teaching hospitals in South-Western Nigeria and estimating the corresponding annual effective dose equivalents. The findings are intended to provide evidence-based insights for improving shielding effectiveness, enhancing occupational safety, and strengthening radiation-protection policies within healthcare facilities in the region.

MATERIALS AND METHODS

Study Area

This research was carried out in four different teaching hospitals, namely; LAUTECH Teaching Hospital (LTH) Ogbomoso, BOWEN Teaching Hospital, Ogbomoso, UNIOSUN Teaching Hospital (UTH), Osogbo, and University of Medical Sciences Teaching Hospital, (UNIMEDTH), Ondo. Where the radiation exposure were measured. The Ladoke Akintola University of Technology (LAUTECH) Teaching Hospital is located in Ogbomoso, Oyo State, in the South-West geopolitical zone of Nigeria, Ogbomoso at geographical coordinates that lies approximately between latitude 8 °08′N and longitude 4 °15′E, and was established in 1991 to support the medical faculty at LAUTECH which was initially founded in 1990. The hospital plays a pivotal role in medical education and healthcare delivery, serving as a training ground for medical student, nurses and other healthcare professionals while also providing healthcare services to the public. BOWEN Teaching Hospital (BTH), located in Ogbomoso, Oyo State, Nigeria. At the geographical coordinates approximately 8.13443 °N latitude, 4.23449 °E longitude and was founded in 1945 by the Nigeria Baptist Convention. It was established as point of the broader effort to improve healthcare service in Nigeria, especially in the southwestern region. The hospital was initially set up as a missionary hospital. It offers internship, clinical rotations and residency programs. BTH has contributed significantly to improving healthcare access in the region, especially in rural areas. UNIOSUN is a state-owned medical teaching hospital located in Osogbo, Osun State, Nigeria at the geographical coordinates 7.77856 ° N, 4.55146 °E (7 ° 46′ 43″ N, 4 ° 33′ 5″ E). It provides tertiary healthcare and supports undergraduate medical students from Osun State University. UTH was previously known as LAUTECH Teaching Hospital, (LTH), Osogbo. The University of Medical Sciences Teaching Hospital (UNIMEDTH) is located in Medical Village, along Laje Road in Ondo City, Ondo State, Nigeria, at the geographical coordinates 7 °14′35.369″ N latitude and 5 °11′59.777″ E longitude. University of Medical Sciences, Ondo, Ondo State at the radiology department of both the University and Teaching Hospital (University of Medical Sciences Teaching Hospital (UNIMEDTH)), Ondo, Ondo State. UNIMED is a medical state university situated in Ondo town, established during the regime of formal governor Dr. Olusegun Mimiko. UNIMED was designed to integrate the training of health professionals, producing graduate that see the health profession as an integral part rather than as antagonistic parts. It will be a major innovative contribution to human resource development and the fostering of inter-professional harmony in the Nigeria health sector. The Radiology department at the University of Medical Sciences Teaching Hospital (UNIMEDTH), Ondo, is tasked with providing a comprehensive spectrum of diagnostic and therapeutic imaging services, encompassing conventional radiography, ultrasonography, and specialized radiologic procedures. The department also functions as an integral component of the clinical training framework for students of the University of Medical Sciences, Ondo. It facilitates the acquisition of theoretical knowledge and practical skills in the field of Radiography and Radiation Science, thereby equipping graduates with proficiency in advanced imaging modalities, as well as in the principles and application of radiation safety and protection. Such integration of clinical service delivery with academic training underscores the department's dual role in promoting both healthcare provision and professional education. The diagnostic procedures at the radiation unit of all these hospitals encompasses a range of imaging techniques primarily used to visualize internal structures of the body. It typically involves a few key steps, depending on the type of imaging or treatment being performed.

2.2 Measurement of X-ray Exposure

To assess the radiation exposure levels within the radiology unit and the surrounding areas, a handheld

Radiation Alert 200 (RAM 200) was used. This pre-calibrated devices measures radiation dose rates in microsieverts per hour (µSv/hr), the standard unit for background radiation. Three distinct location were randomly selected for data collection: Exposed room (radiology unit), Non-exposed room (waiting room), and Cubicle corridor (partially exposed area). RAM 200 was positioned 1.2 meters above ground level, simulating the height of the liver and kidney of human beings. Background radiation levels were recorded at each data point. Three measurements were taken at each location to ensure representative data. Radiation Alert Monitor 200 is shown in Plate 1 below.

Plate 1: Radiation Alert Monitor 200

2.3 Estimation of Annual Effective Dose Equivalent

Estimating the annual effective dose of radiation involves calculating the total dose received from various sources over a year, typically measured in sieverts (Sv) or millisieverts (mSv). The formula for estimating the annual effective dose (AEDE) of radiation in (µSv/hr) **c**an be estimated using the following model:

$$AEDE = \frac{D\ (\mu Sv/hr)\ X\ T\ (hr/yr)\ X\ 0.8}{1000} \quad (1)$$

Where:

- D = Dose from each radiation source (µ Sv/hr)
- T = Time in hour for one year (8760 hr/yr)

This model is based on the International Commission on Radiological Protection (ICRP) recommendations.

RESULTS AND DISCUSSIONS

3.1Absorbed Dose Rate and Annual Effective Dose Equivalent

Table 1, 2, 3 and 4 shows the measured absorbed dose rate and the annual effective dose equivalent for LAUTECH Teaching Hospital (LTH) Ogbomoso, BOWEN Teaching Hospital, Ogbomoso, UNIOSUN Teaching Hospital (UTH), Osogbo, and University of Medical Sciences Teaching Hospital, (UNIMEDTH), Ondo respectively.

Table 1: Measured absorbed dose rate and the estimated annual effective dose equivalent in the Radiology department of LAUTECH Teaching Hospital, Ogbomoso, Oyo State.

Location	Absorbed Dose Rate (µSv/hr)	Annual Effective Dose Equivalent (mSv/yr)
X-ray Room	0.188±	1.319
Beside X-ray Room	0.180±	1.261
Front of X-ray Room	0.078±	0.841
Back of X-ray Room	0.179±	1.260
Waiting Room	0.089±	0.622
Mean	**0.143**	**1.061**

Table 2: Measured the absorbed dose rate and estimated annual effective dose equivalent in radiology department, BOWEN Teaching Hospital (BTH), Ogbomoso.

Location	Absorbed Dose Rate (µSv/hr)	Annual Effective Dose Equivalent (mSv/yr)
X-ray Room	0.187±	1.308
Beside X-ray Room	0.135±	1.062
Front of X-ray Room	0.152±	0.946
Back of X-ray Room	0.125±	0.665
Waiting Room	0.125±	0.876
Mean	**0.145**	**0.971**

Table 3: Measured the absorbed dose rate and estimated annual effective dose equivalent in radiology department, UNIOSUN Teaching Hospital (UTH), Osogbo.

Location	Absorbed Dose Rate (µSv/hr)	Annual Effective Dose Equivalent (mSv/yr)
Waiting Room	0.098	0.687
	0.089	0.624
	0.122	0.855
	0.077	0.539
	0.098	0.687
	0.122	0.855
	0.134	0.939
	0.089	0.624
	0.110	0.771
Mean (S.D)	**0.104 (0.019)**	**0.731 (0.132)**
Common Room	0.314	0.939
	0.122	0.855
	0.200	1.402
	0.179	1.254
	0.143	1.002
	0.134	0.939
	0.110	0.771
	0.143	1.002
	0.143	1.002
Mean (S.D)	**0.165 (0.062)**	**0.018 (0.194)**
Conventional Room	0.098	0.687
	0.122	0.855
	0.110	0.771
	0.077	0.539
	0.188	1.318
	0.167	1.170
	0.122	0.855
	0.122	0.855
	0.167	1.170
Mean (S.D)	**0.130 (0.036)**	**0.913 (0.254)**

Table 4: Measured the absorbed dose rate and estimated annual effective dose equivalent in radiology department, University of Medical Sciences Teaching Hospital (UNIMEDTH), Ondo.

Location	Absorbed Dose Rate (µSv/hr)	Annual Effective Dose Equivalent (mSv/yr)
X-ray Room	0.320	2.243
	0.240	1.682
	0.220	1.542
	0.190	1.332
	0.188	1.318
	0.180	1.261
	0.240	1.682
	0.220	1.542
	0.200	1.402
Mean (S.D)	**0.222 (0.043)**	**1.445 (0.323)**
Cubicle Corridor	0.130	0.911
	0.120	0.841
	0.150	1.051
	0.125	0.876
	0.125	0.876
	0.122	0.855
	0.110	0.771
	0.115	0.806
	0.112	0.785
Mean (S.D)	**0.123 (0.012)**	**0.864(0.084)**
Waiting Room	0.098	0.687
	0.090	0.631
	0.070	0.491
	0.060	0.420
	0.077	0.540
	0.089	0.624
	0.100	0.701
	0.065	0.456
	0.095	0.666
Mean (S.D)	**0.083 (0.015)**	**0.579 (0.105)**

3.1.1 LAUTECH Teaching Hospital

The annual effective dose equivalent estimated at LAUTECH Teaching Hospital for the X-ray room, Beside, front and back of X-ray room and waiting room range from 0.622 mSv/yr to 1.319 mSv/yr with mean value 1.061 mSv/yr which are below ICRP occupational dose limit of 20 mSv/yr and this suggests that radiology staff at this location are not at immediate risk of radiation. LTH presents a more varied pattern. Statistical analysis shows significant differences ($P < 0.05$) in radiation exposure at the back and beside the X-ray room during multiple comparison tests, while no significant differences were found in the front X-ray room, main X-ray room, and waiting room. The significant P-values suggest localized hotspots of scatter or leakage radiation at the back and side of the X-ray room, possibly due to design weaknesses, equipment positioning, or inadequate shielding in those specific directions. This finding is also consistent with (UNSCEAR, 2020) data which shows that engineering controls (structural design) are the most reliable method of minimizing occupational exposure. Locally, Nigerian studies (Adedeji *et al.*, 2019) have consistently reported challenges such as aging equipment, insufficient shielding, and poor maintenance as major contributors to scattered radiation exposure. The front X-ray room and waiting room, on the other hand, likely benefit from structural shielding and lower occupancy times, keeping exposure levels negligible.

3.1.2 BOWEN Teaching Hospital

The annual effective dose equivalent for all the five locations; X-ray room (1.308 mSv/yr), beside of X-ray room (1.062 mSv/yr), front of X-ray room (0.946 mSv/yr) and back of X-ray room (0.665 mSv/yr) and waiting room (0.876 mSv/yr) at BOWEN teaching hospital. The study shows that the radiation levels around the X-ray department are generally within acceptable limits for public exposure, with a mean value of 0.971 mSv/yr. However, the doses recorded inside and beside the X-ray room exceed the 1 mSv/year public limit, implying the need for restricted access**,** possible shielding improvements and periodic monitoring. Implementing these measures will ensure that the department fully complies with international radiation safety standards while maintaining a safe environment for both workers and the public. At BTH, no significant differences in radiation exposure ($P > 0.05$) were found across all measured areas: X-ray room, front X-ray room, waiting room, and beside X-ray room. This uniformity across high and low-risk zones suggests a high level of structural integrity and shielding efficiency. Even peripheral areas such as the waiting room and beside the X-ray room do not show elevated or variable radiation levels, indicating that scatter radiation is effectively contained. Thus, BTH demonstrates a model radiation safety profile, with both absorbed dose rate and the estimated annual effective dose equivalent being well-managed and statistically uniform across areas of different risk levels.

3.1.3 UNIMED Teaching Hospital

The annual effective dose equivalent estimated across three key areas of the X-ray department at UNIMEDTH; **(**X-ray Room**,** Cubicle Corridor**,** and Waiting Room) demonstrate the variations in exposure levels experienced by workers within (1.261 – 2.243 mSv/yr) with mean value 1.445 mSv/yr, (0.771 – 1.051 mSv/yr) with mean value 0.864 mSv/yr, and (0.420 – 0.701 mSv/yr) with mean value 0.579 mSv/yr respectively. All these radiation levels measured at UNIMEDTH demonstrate overall compliance with international radiation protection standards. The X-ray room shows elevated but occupationally acceptable levels, while the corridor and waiting room remain within safe limits for public exposure. At UNIMEDTH, no statistically significant differences ($P > 0.05$) in radiation exposure were found among the X-ray room, cubicle corridor, and waiting room. This suggests a homogeneous radiation distribution within these areas, albeit at different dose magnitudes. The X-ray room, being the primary source zone, predictably has the highest radiation levels. However, this is well controlled, often through lead shielding and operational protocols. The cubicle corridor and waiting room are not directly exposed to the primary beam, radiation in these areas arises from scatter or leakage. Despite these differences in function and expected exposure, the lack of significance implies that shielding and structural design are effective in minimizing exposure gradients. This finding is consistent with (UNSCEAR, 2020) data which shows that engineering controls in the sense of structural designs are the most reliable method of minimizing occupational exposure. Locally, Nigerian studies (Adedeji *et al.*, 2019) have consistently reported challenges such as aging equipment, insufficient shielding, and poor maintenance as major contributors to scattered radiation exposure. Therefore, while the X-ray room remains the controlled high-dose area, the equivalent and effective doses in surrounding zones are statistically similar, emphasizing adequate safety measures across UNIMEDTH.

3.1.4 UNIOSUN Teaching Hospital

UTH estimated annual effective dose equivalent for the three locations at radiology department; Waiting Room, Common Room, and Conventional Room demonstrate generally effective radiation protection practices. AEDE range within 0.539–0.939 mSv/yr with mean value 0.731 mSv/yr for the waiting room, 0.771–1.402 mSv/yr for common room with mean value 0.018 mSv/yr, and the conventional room 0.539–1.318 mSv/yr with mean value 0.913 mSv/yr. However, the Common Room exceeds the public dose limit (1 mSv/yr according ICPR) and requires further attention to shielding, occupancy control, or area classification. Overall, the department remains largely compliant with international standards, provided that corrective measures are taken in borderline areas to maintain long-term radiological safety. Similarly, UTH exhibits no significant P-values (< 0.05) in the X-ray room, common room, and conventional room. The X-ray room maintains its role as the primary radiation source but does not statistically differ in exposure levels from adjacent rooms. This uniformity

indicates that radiation control protocols are consistently applied, preventing unsafe accumulation in non-primary areas. The Annual Effective Dose across these locations remains within internationally recommended limits of 0.73 ± 0.13 mSv/yr and 1.45 ± 0.32 mSv/yr, depending on the site, showing that personnel and patients are not subject to differential risk based on room usage in UTH. The annual effective dose measured across the radiology units in the hospitals studied ranged between 0.73 ± 0.13 mSv/yr and 1.45 ± 0.32 mSv/yr, depending on the site. These values are well below the ICRP occupational dose limit of 20 mSv/yr averaged over five years and the 50 mSv single-year maximum. While this suggests that radiology staff are not at immediate risk of exceeding internationally accepted dose thresholds, it is important to emphasize that no dose of ionizing radiation is entirely safe because of the stochastic nature of long-term effects such as malignancies (ICRP, 2007).

3.2 General Observations on the Radiology Departments

The variation in measured absorbed dose rates between X-ray rooms and adjoining areas underscores the importance of shielding and room design. Facilities with well-structured walls, proper door closures, and minimal leakages recorded lower dose values in adjoining spaces. This finding is consistent with (UNSCEAR, 2020) data which shows that engineering controls are the most reliable method of minimizing occupational exposure. Locally, Nigerian studies (Adedeji *et al.*, 2019) have consistently reported challenges such as aging equipment, insufficient shielding, and poor maintenance as major contributors to scattered radiation exposure. Radiation exposure varies across hospital areas, the X-ray room is the primary radiation zone where direct exposure from the X-ray machine occur with highest radiation but well controlled. While other locations like the cubicle corridor, conventional rooms has the scattered radiation from the X-ray room. Exposure here is from leaked radiation likewise the waiting room and the exposure here is negligible due to structural shielding and intermittent occupancy. In summary, radiation exposure levels across hospital environments are largely determined by their proximity to the X-ray source and the effectiveness of structural shielding. UNIMEDTH and UTH show no significant dose variation among their locations, indicating consistent application of radiation protection standards. LTH reveals localized exposure concerns, necessitating further shielding at the back and side of the X-ray room. BTH displays ideal radiation uniformity, suggesting optimal design and maintenance of radiation control systems.

CONCLUSION

The absorbed dose rate was measured and the annual effective dose equivalent were estimated for four teaching hospitals; LTH, BTH, UTH, and UNIMEDTH using a handheld Radiation Alert 200 (RAM 200), Radiation levels were generally uniform across rooms in UNIMEDTH and UTH, indicating effective shielding practices, whereas LTH showed localized hotspots near the X-ray unit, suggesting insufficient structural protection; BTH demonstrated consistently well-controlled exposure conditions. The annual effective dose equivalents remained below international occupational limits in all hospitals studied. These findings provide baseline evidence on X-ray leakage and occupational risk awareness.

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