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Evaluation of shielding thickness in the radio-diagnostic facility of Turai Yaradua Maternity and Children Hospital Katsina, Katsina State, Nigeria

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Abstract

The medical application of radiation can induce radio-biological effects which makes it necessary to ensure some safety precautions, of which, room shielding is one of those safety measures. The aim of this study was to assess the lead wall lining thickness of the radio-diagnostic room of Turai Yaradua Maternity and Children Hospital Katsina. The required lead wall lining thickness was estimated using NCRP 147 formulations. The measured area of the radio-diagnostic room was 39.44 m^2. The maximum required lead thickness values were estimated as 1.1 mm and 0.8 mm for erect and supine radiographic positions, respectively, while, the installed lead wall lining thickness was 2 mm. The area monitoring revealed that there was no leakage radiation. Though, the shielding was adequate and there was no leakage radiation, it is however recommended that the radiation workers maintain maximum distance, minimum exposure time and use shielding barrier in order to ensure minimal occupational radiation exposure. Periodic area monitoring is also encouraged in order to prevent radiation exposure of the members of the public.

Keywords: Radiation; Radio-diagnostic room; Lead wall lining thickness; NCRP 147; Leakage radiation

1. Introduction

The application of ionizing radiation in medicine can be for diagnostic or therapeutic purposes. Radiation protection and the use of appropriate shielding materials have become essential in recent years due to high number of cancer patients worldwide [1]. Exposure of patient, radiation workers and the members of public may lead to both deterministic and stochastic effects even at low doses [2]. And because of the risks associated with the use of ionizing radiation, it has become essential that the fundamental principles of radiation protection specifically: justification of practice, optimization of protection and dose limitation are appropriately followed [3]. The radio-diagnostic room where various forms of radiographic investigations are carried out must be adequately shielded. Inadequate shielding of the radio-diagnostic room would result to radiation exposure to members of the public due to radiation leakage [2]. Therefore, the X-ray beam must be confined to the radio-diagnostic room by installing wall shielding using materials such as lead, copper and concrete [4].

In the planning of any radio-diagnostic facility, one of the important priorities is to ensure that persons in the vicinity of the facility are not exposed to leakage radiation. The current recommended exposure limits are 5.0 mSv/year and 1.0 mSv/year for occupationally exposed persons and the members of the public respectively [5, 6]. And for the fetus, the annual maximum permissible dose of 0.5 rem or 5mSv is recommended [7]. The standard or general concept of provision of radiation shielding barrier for radiation installations begins with professional design of the radiation facility by group of qualified experts to ensure that the required degree of protection is installed [7].

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Several studies on shielding thickness assessment in radio-diagnostic facilities have been carried out. Anizor et *al*. [9] reported on the evaluation of the effectiveness of structural shields of x-ray facilities in Asaba, Delta State. Based on NCRP 49 recommendations, the study findings revealed that the lead thickness was adequate for secondary barriers in all the facilities but inadequate for primary barriers in facilities B and C. The study recommended that prior to construction/design/use of radiographic facility, regulatory bodies such as the NNRA should be aware and the employer must seek authorization, similarly a qualified expert should be contracted during the above process. Akintayo *et al.* [1] reported on shielding assessment in three diagnostic X-ray facilities in Asaba, South South Nigeria. The shielded air kerma rate to the control console was adequate, but made recommendation that the contribution of side scatter was noticed to have increased the occupational dose because of the use of a lead screen, which in most cases does not completely shield the right and left side of the radiographer. The study recommended that shielding in diagnostic radiology be taken as seriously as that of CT shielding and the control console should be made to completely shield personnel to avoid unnecessary scatter radiation. Study by Kiragga [2] on effectiveness of the shielding mechanism in rooms housing x-ray diagnostic equipment's in Mulago Hospital, Uganda revealed that the radiation in all the controlled areas were highly scattered. Furthermore, the occupational exposure levels were below the recommended dose limits. Some of the workers adhered to the ALARA principle. The high equivalent doses in some imaging rooms could be attributed to the high work load due to scatter radiation. Gemanam *et al*. [10] conducted a study on evaluation of protective shielding thickness of Benue State University Teaching Hospital radiology room. The study revealed that the protective shielding parameters evaluated were in conformity with the recommended maximum limits by the National Council for Radiation Protection and Measurements (NCRP 49 and 151). Several other studies have evaluated the effectiveness of structural shielding barrier using different recommendations with a view to establishing a standard that would help determine the thickness of materials needed for a given x-ray room based on geographical location, radiographic workload, occupancy factor and use factor.

Having seen the importance of assessing the integrity of the radio-diagnostic room shielding material, the aim of this study is to evaluate the shielding thickness of the radio-diagnostic room Turai Yaradua Maternity and Children Hospital Katsina State.

2. Material and methods

2.1. Materials

The materials used in this study were as follows: Measuring tape 5m (16ft), Calibrated RDS-31 survey meter (with serial number 2100332, display range: 0.01µsv/h-100msv/h 0.01µsv-10sv, calibration date 13-04-2022 at National Institute of Radiation Protection and Research) and Vanier caliper.

2.2. Method

A prospective study was carried out in the radio-diagnostic room containing a conventional X-ray machine. The shielding calculations were carried using Equations (1) to (4). The following factors were measured and used for the calculation: distance (D) from x-ray tube to the wall, average number (N) of patient per week, use factor (U) the fraction of the primary beam workload that was directed towards a given primary barrier depends on the radiographic installation and the barrier of concern NCRP 147, Air Kerma (K). The recommended quantity for shielding design calculations for x rays was air kerma (K) (NCRP, 2005). occupancy factor (T) which according to NCRP 147 is the fraction of the working hours in the week that a given person would occupy the area, averaged over the year, shielding design goal (P) for both controlled and uncontrolled area from NCRP 147) was the levels of air kerma used in the design calculations and evaluation of barriers constructed for the protection of employees and members of the public, thus according to NCRP 147 The weekly shielding design goal for a controlled area was an air-kerma value of 0.1 mGy $week^{-1}$ and The weekly shielding design goal for an uncontrolled area was an air-kerma value of 0.02 mGy $week^{-1}$, thickness of the installed lead. According to NCRP 147 Report, the KERMA in the occupied area may have contribution from primary and secondary radiation, thus in estimating the required lead shielding primary and secondary radiation were considered.

Measuring tape was used to measure the room dimension and distance from x-ray tube to the walls where the four walls were named wall 1, wall 2, wall 3 and wall 4 respectively. This study estimated the primary and secondary unshielded Air kerma at Erect Bucky and supine position. According to geometry of x-ray room, for Erect Bucky the x-ray tube was directed horizontally toward wall 1, so all the walls except wall 1 were assumed to be secondary barrier and wall 1 are assumed to be primary barrier, and at supine position all the four walls are assumed to be secondary barrier and the floor were assumed to be primary barrier. Area behind wall 1 was uncontrolled area an office that is adjacent to x-ray room, therefore the occupancy factor according to NCRP 147 is (T=1). Area behind wall 2 was uncontrolled area with maximally exposed individual that is a corridor with occupancy factor (T=1/5). Area behind wall 3 is controlled area an x-ray control console with use factor (T=1). Area behind Wall 3 was an uncontrolled area vehicular drop off area and according to NCRP 147 the use factor (T=1/40), because it was assumed that a given member of the public will spend an average of 1h/week while the x-ray beam was activated all the values obtained are from NCRP 147. According to NCRP 147 the weekly unshielded primary Air kerma Kp(0) in occupied area due to N patient examine per week in the room was calculated using:

$$Kp(0) = {(Kp^1 \times UN)}/{dp^2} \text{ ....(1)}$$

The unshielded primary Air Kerma per patient Kp^1 at 1m distance is given in the Table 1 from NCRP 147 [8].

Table 1 Unshielded primary air kerma per patient [Kp^1 (in mGy patient^{-1})] for the indicated workload [Wnorm (mA min patient^{-1})] and workload distribution, normalized to primary beam distance dp =1m (NCRP 147, 2005)

Workload Distribution[a]	W_{norm} (mA min patient^{-1})[b,c]	K_P^1 (mGy patient^{-1})[d]
Rad Room (chest bucky)	0.6	2.3
Rad Room (floor or other barriers)	1.9	5.2
Rad Tube (R&F Room)	1.5	5.9
Chest Room	0.22	1.2

Equation (2) was used to determine the required transmission for both concrete and lead.

$$Bp(X\ barrier) = {{P}/{T}}/{Kp(0)} \text{ ....(2)}$$

where, P is the shielding design goal (Header *et al.*, 2014).

Thus, to calculate the weekly unshielded secondary Air Kerma Ksec (0) in occupied area due to N patient examine per week in the room Equation (3) was used from NCRP 147,

$$k_{sec}(0) = {k_{sec}^1}/{d_{sec}^2} \times N \text{ ....(3)}$$

The unshielded secondary Air Kerma per Patient K^1sec was also obtained from NCRP 147 so also the Barrier transmission was calculated using Equation (4) for both concrete and lead.

$$Bsec(X\ barrier) = {{P}/{T}}/{Ksec(0)} \text{ ....(4)}$$

Where, P is the shielding design goal [12].

The barrier transmission calculated for both primary and secondary barrier will be used to trace the required lead thickness on primary and secondary transmission curve from NCRP 147 [8] as shown in Figure 2 to 4 respectively.

One calibrated Survey meter (Rados RDS-31) was obtained from the Nigerian Nuclear Regulatory Authority. The Rados-31 meter was used to assess the adequacy of installed shielding to protect members of the public from leakage radiation.

3. Results and discussion

Results were obtained after detailed computations were carried out from the measured radiographic parameters/shielding distances at Turai Yaradua Maternity and Children Hospital Katsina.

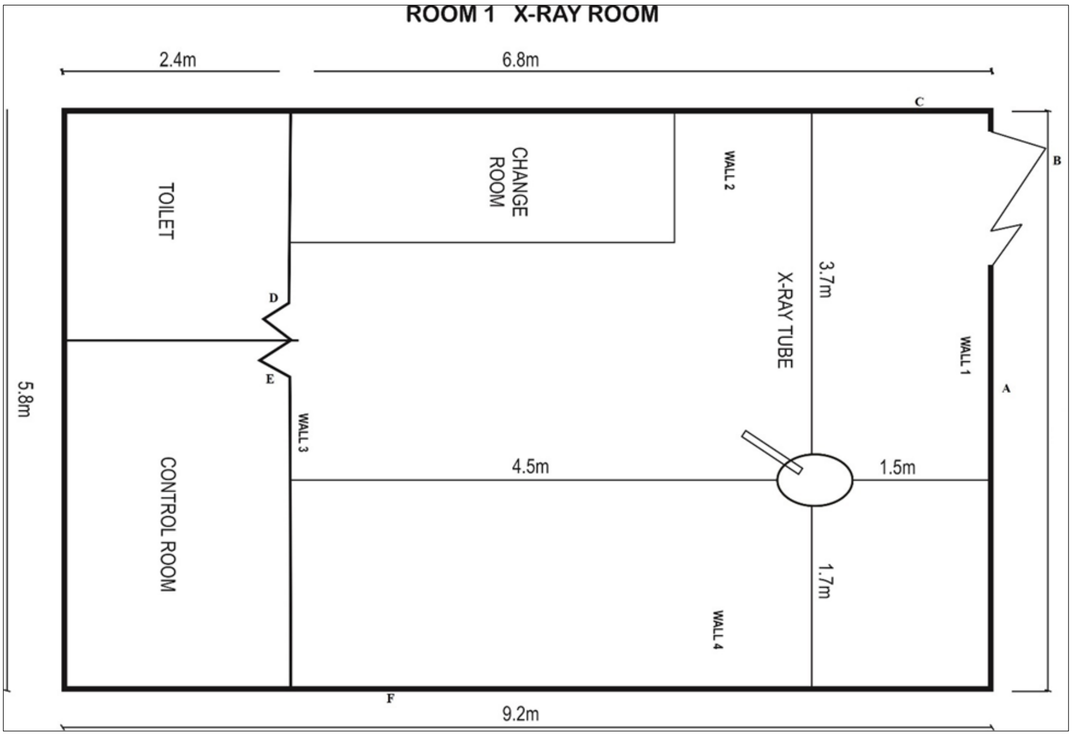

Figure 1 Radio-diagnostic room dimension

The area specification of Room 1 (conventional x-ray room) measures at 39.44 m^2. This implies that laser radiation will reach the walls according to the inverse square law. The Area of the rooms is in line with the Nigerian nuclear regulatory authority (NNRA) and world health organization (WHO) room specifications of ≥16 m^2 and 16-24 m^2 diagnostic radiographic rooms, respectively [9]. Other room specifications such as the concrete walls and the two-millimeter lead thickness were installed on all the walls of the radiographic room as shown in Figure 1.

Table 2 Lead thickness calculation for Room 1 (x-ray room)

Designation	**Distance from the source d(m)**	**ERECT BUCKY**						**SUPINE POSITION**				
		Kp (0) (mGy /w)	**Ksec (0) (mGy /w)**	**Bp(x)**	**Required lead Thickness (mm)**	**B sec(x)**	**Required lead Thickness (mm)**	**Kp(0) (mGy /w)**	**Ksec (0) (mGy /w)**	**Bp(x)**	**Bsec(x)**	**Required lead Thickness (mm)**
Wall 1	1.5	0	0.313	0	0	6.4×10^{-2}	0.3	0	2.01	0	9.95×10^{-3}	0.8
Wall 2	3.7	22.34	0	4.5×10^{-3}	1.1	0	O	0	0.33	0	3.0×10^{-1}	<0.2
Wall 3	4.5	0	0.035	0	0	2.857	0	0	0.22	0	4.5×10^{-1}	<0.2
Wall 4	1.7	0	0.244	0	0	4.1×10^{-1}	<0.1	0	1.563	0	5.1×10^{-1}	<0.2

Table 2 shows the required lead thickness which was calculated according to equations (1) to (4) for primary and secondary barriers respectively. The maximum required lead thickness calculated were 1.1mm and 0.8 mm for erect Bucky and supine positions respectively. The erect Bucky position values were obtained when all the walls were assumed to be primary-secondary barriers, while the supine position values were obtained when all the walls were assumed secondary barrier. The results obtained were traced on figure 2 to 4 respectively. The results were compared with related studies which shows dissimilarity with the findings of Yusuf et al. [11], Header et al. [12] and Usman et al. [13]. This study however is in agreement with the findings of Anizor et al. [9] and Gemanam et al. [10].

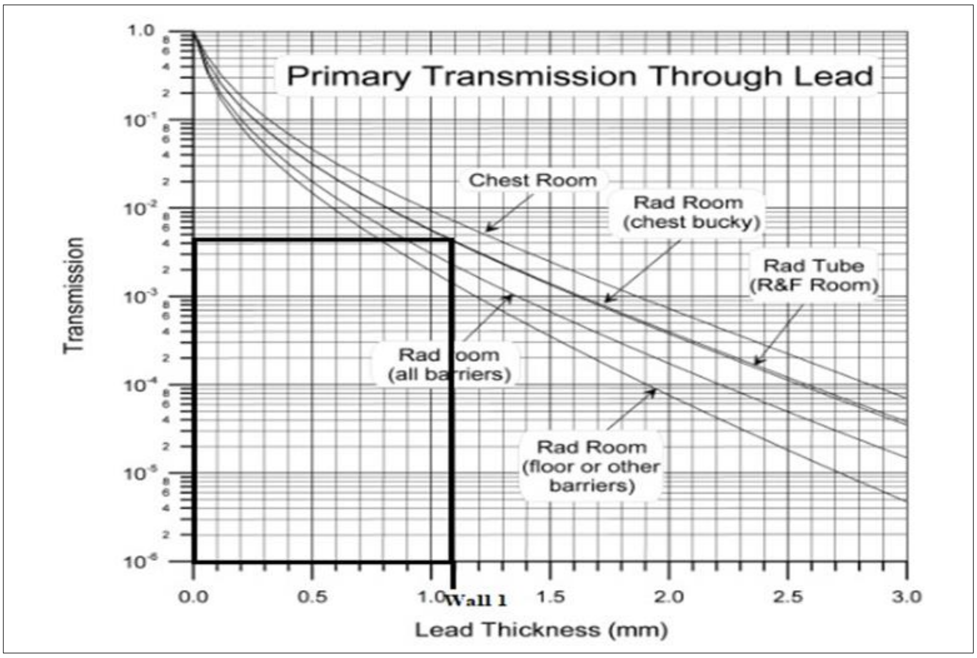

Figure 2a Primary transmission through lead calculated for chest Bucky Room 1 (x-ray room)

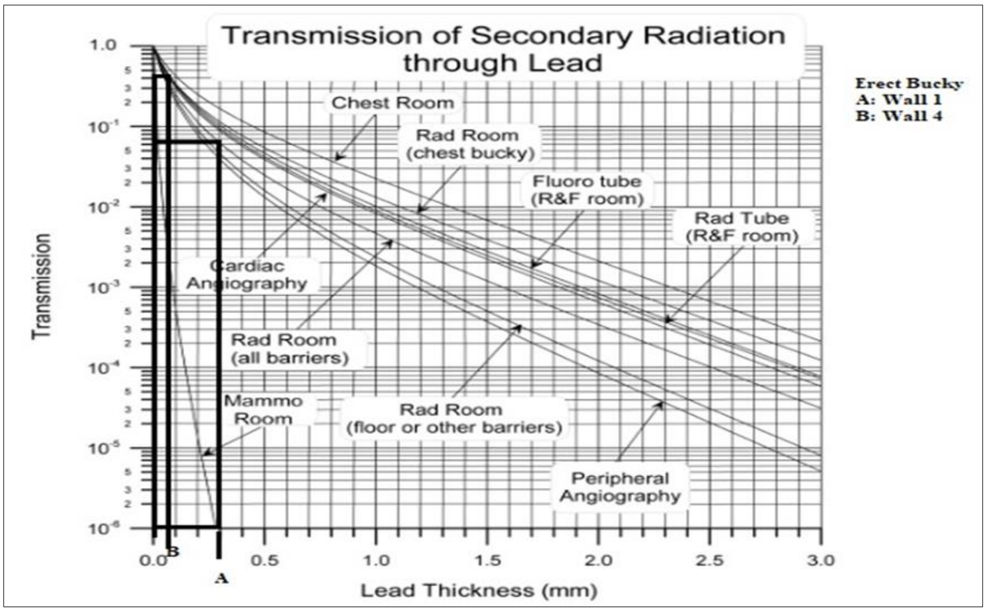

Figure 2b Secondary transmission through lead calculated for Erect Bucky Room (x-ray room)

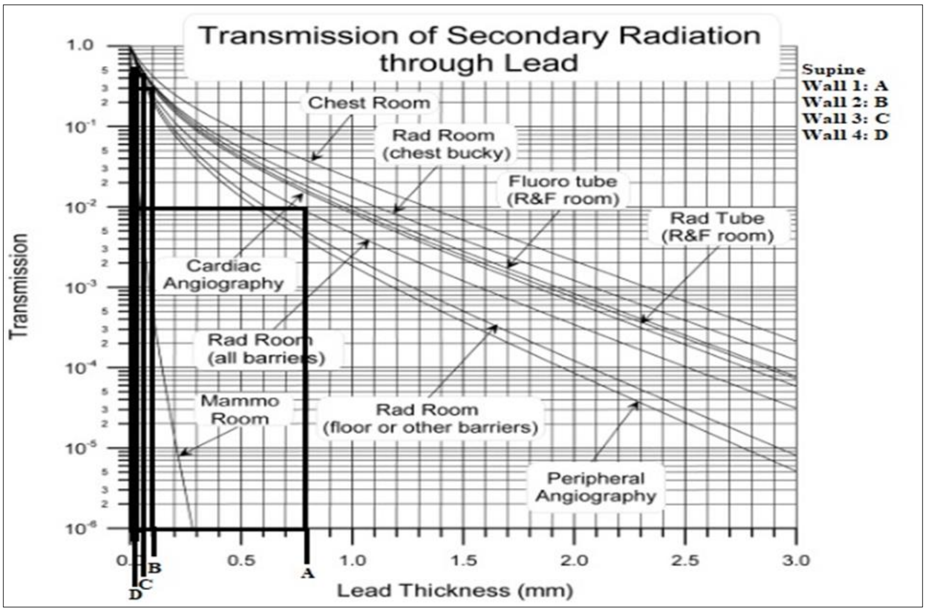

Figure 3 secondary transmission through lead for Supine Position Room 1 (x-ray room)

Table 3 Area Monitoring of Some Selected Locations Around Room 1 At Maximum operating potential

LOCATIONS	Dose Rate Measurements (µsv/h)			Mean Measured Dose Rate ± SD (µsv/h)
	First	Second	Third	
A	0.16	0.15	0.14	0.15 ±0.01
B	0.16	0.17	0.15	0.16 ±0.01
C	0.13	0.14	0.15	0.14 ±0.01
D	0.11	0.13	0.15	0.13 ±0.02
E	0.13	0.11	0.15	0.13 ±0.02
F	0.14	0.15	0.13	0.14 ±0.01

Six different locations with three different dose rate measurement were measured at location A to F. Table 3 shows the Area Monitoring of Some Selected Locations around Room 1. At Maximum Exposure, the mean dose rate and standard deviation was calculated, the maximum and minimum values obtained for mean dose rate and standard deviation were 0.16 ±0.01µsv/h for location B (at entrance door) and 0.13 ±0.02 µsv/h for location D and E (toilet and control room) the result obtained are within recommended dose limit of 1mSv and 5 mSv for members of public and occupational workers, respectively.

The study shows similarity with the findings of Omojola et al. [14], who concluded that the mean ADR and shielding design goals in the controlled and supervised areas from the three studied X-ray units were within acceptable limits for occupationally exposed staff and the public [13, 15] respectively.

The study shows a very good similarity with the findings of Joseph et al. [15], who study on Assessment of Radiation Leakage from Diagnostic Rooms of Radiology Department of a Teaching Hospital in Kano, Northwestern Nigeria

4. Conclusion

This study found that the level of radiation shielding thickness in Turai Yaradua Maternity and Children Hospital Katsina, were within the acceptable level, hence, meeting the National and International Standards. The shielding design parameter (thickness) studied at the Turai Yaradua Maternity and Children Hospital Katsina, were calculated using air kerma model for diagnostic X-ray shielding from NCRP Report No 147. The shielding parameter (thickness) are within recommended safety limit specified by the National Council on Radiation Protection and Measurement (NCRP). The calculated barrier thickness was found to be less than (<2mm lead). This implies that the walls of the diagnostic rooms of the hospitals investigated have adequate protective shielding and can accommodate future increase in the number of patients examined in the diagnostic rooms per week.

Compliance with ethical standards

Acknowledgments

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Disclosure of conflict of interest

No conflict of interest to be disclosed.

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