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The Study of Shielding Design Parameter (Thickness) in Two Health Tertiary Institutions in Katsina Metropolis, Nigeria

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Abstract
The safety of the patient is of highest importance during diagnostic imaging which uses various forms of ionizing radiations mainly photons (x-rays and gamma rays). Both the patient and personnel working in the diagnostic facility may be exposed to unintentional source of radiations during diagnostic imaging. This study was conducted at the Federal Medical Center, Katsina and General Amadi Rimi Specialist Hospital, Katsina to assess the shielding adequacy of the barriers required to attenuate the intensity of X-ray to recommended limit. The National Council on Radiation Protection and measurement (NCRP), Report No 147 was used to evaluate the shielding barriers of the radiographic rooms in the two facilities. Calculation was done using the number of patients (N), occupancy factor (T), Design dose limit (P) and the distance to the occupied area (controlled and uncontrolled area). The result shows that the room area meets the recommendation of Nigeria Nuclear Regulatory Agency (NNRA) of at least 16 m² and the shielding requirement for the primary barrier is slightly higher than secondary barrier of each room. The calculated shielding requirement for the primary barrier of room I, room II and room III of Federal Medical Center, Katsina and room IV of General Amadi Rimi Specialist Hospital, Katsina are 0.59 mm, 0.46 mm, 0.36 mm and 0.48 mm respectively. The maximum calculated shielding requirement for the secondary barriers in room I, room II, and room III of Federal Medical Center, Katsina and room IV of General Amadi Rimi Specialist Hospital, Katsina are 0.55 mm, 0.48 mm, 0.63 mm and 0.48 mm respectively. The ratio of the calculated to current material thickness is less than one (<1) for all the rooms.This indicates that the shielding barriers in the facilities are adequate. Hence, can accommodate future increase in the number of patients examined in the diagnostic rooms per week.

Keywords: x-ray room, NCRP, room design, shielding, barrier thickness, safety limit.

INTRODUCTION
Ionizing radiations used during diagnostic imaging and radiation therapy could exit as photons (*x*-ray and gamma rays) or particles (electron, neutron, proton, alpha and beta), which could be harmful to people and the environment as suchthe shielding of this radiation is of utmost importance.The medical exposureto radiation whose effect is usually considered to be minimal (NEA, 1994)involve the use of ionizing radiations in hospitals, dental care, clinics and in medical research to help diagnose and treat conditions under the supervision of professional(s) in this field. The benefits derived from this procedure(s) greatly outweigh the potential risks (HPS, 2021).During diagnostic imaging both the patient and personnel working in the diagnostic facilities may be exposed to unintentional source of radiation such as leakage radiation, internal patient scatter and collimator scatter which are referred to as secondary field dose and are very small relative to the primary field doses but are given to a large part

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of the body (ICRP, 2005). Secondary fielddosehave long term effects and may increases the potential risk of secondary cancer (Xu, 2008). Adequate care and protection should be taken due to the hazards associated with the use of radiations, it is important that the fundamental radiation protection principle of justification of practice, optimization of protection and dose limit are adhered to strictly and implemented appropriately.

The National Council on Radiation Protection and measurement (NCRP), Report No 147 recommended standard guidelines on calculating and designing shielding barrier thickness of diagnostic x-ray room. The report also showed that all materials can be used for shielding purpose, as confirmed by researchers such asYusuf *et al*., (2012), Esien *et al*., (2013), Vishwanath and Badiger (2014), Joseph *et al*., (2017), Ahmad *et al*., (2018), Dehinde *et al*., (2018) and Abubakar and Sidi (2019). Due to certain characteristics, lead, steel, concrete, glass and gypsum are the most commonly used materials. This research is aimed at conducting quality assessment of radiographic room(s) of the Federal Medical Center, Katsina and General Amadi Rimi Specialist Hospital, Katsina base on the National Council on Radiation Protection and measurement NCRP recommendations.

MATERIALS AND METHOD

Data capturing sheet, radiation survey meter and measuring tape 5m (16.6ft) long were used for measurement to determine the exposure from the source to the barrier at the Federal Medical Center, Katsina and General Amadi Rimi Specialist Hospital, Katsina. For ease of study, we labeled the x-ray rooms. The Federal Medical Center which consists of three x-ray rooms, were labelled room I, room II and room III, located at the main radiology building complex except for room III which is located at accident and emergency radiology department. General Amadi Rimi Specialist Hospital has only one x-ray room labelled room IV located at the radiology department. The x-ray machines in both institutions are conventional x-ray machines with a total filtration of 2.5mmAI. The dimensions of the x-ray rooms and specifications of the machines are listed in table 1.

Table 1: Dimensions and specifications of the x-ray machines of the study areas.

	Federal medical center, Katsina			General Amadi Rimi specialist hospital, Katsina
X-ray room	Room I	Room II	Room III	Room IV
Length (m)	5.0	7.6	3.7	6.5
Breadth (m)	3.5	5.2	3.5	5.3
Height (m)	3.5	3.5	3.5	3.5
Dimension (m^2)	17.50	39.52	13.32	34.45
Wall type	Concrete block	Concrete block	Concrete block	Concrete block
Lead lining height (m)	3.5	3.5	3.5	3.5
Lead lining thickness	0.002	0.002	0.002	0.002
Door type	Wooden board	Wooden board	Wooden board	Wooden board
Height of door (m)	2.0	2.0	2.0	2.0
Width of door (m)	1.1	0.7	1.4	3.0
Lead lining thickness	0.002	0.002	0.002	0.002
Dimension (m^2)	2.2	1.7	2.8	6.0
Control cubicle type	Wooden	Wooden	Wooden	Wooden
Warning lights	Yes	Yes	Yes	Yes
Warning signs	Yes	Yes	Yes	Yes
Machine specification				
Tube current (mA)	400	400		300
Max. tube potential (kV)	150	125		135
Max. Filtration (mmAI)	2.5	2.5	2.5	2.5

Method

The evaluations of the shielding barrier (thickness) of the x-ray facilities were carried out and calculated using NCRP 147. The $\frac{NT}{Pd^2}$model for diagnostic x-ray shielding in NCRP Report No 147 can handle complicated assemblages of x-ray tubes/ positions/workload distributions such as in a radiographic or radiographic/fluoroscopic room. The required barrier thickness is then looked up in the $\frac{NT}{Pd^2}$model graph of NCRP report 147.

Calculation of shielding barrier thickness

The calculations of the thickness of the shielding barriers (primary and secondary barriers) of the two diagnostic facilities were carried out using the NCRP report No. 147 method. The shielding barrier thickness was evaluated using;

$$\frac{NT}{Pd^2} \quad (1)$$

Where N is the number of patients examined per week, P is the design dose limit, Tis the occupancy factor andd is the distance from the x-ray machine to the area of interest.

RESULTS

The schematic diagram of the rooms studied in the research are indicated in figures 1 to 4. The experimental results obtained after detailed computations were carried out from the measured radiographic parameters/shielding and these results are presented in tables 2 to 9.

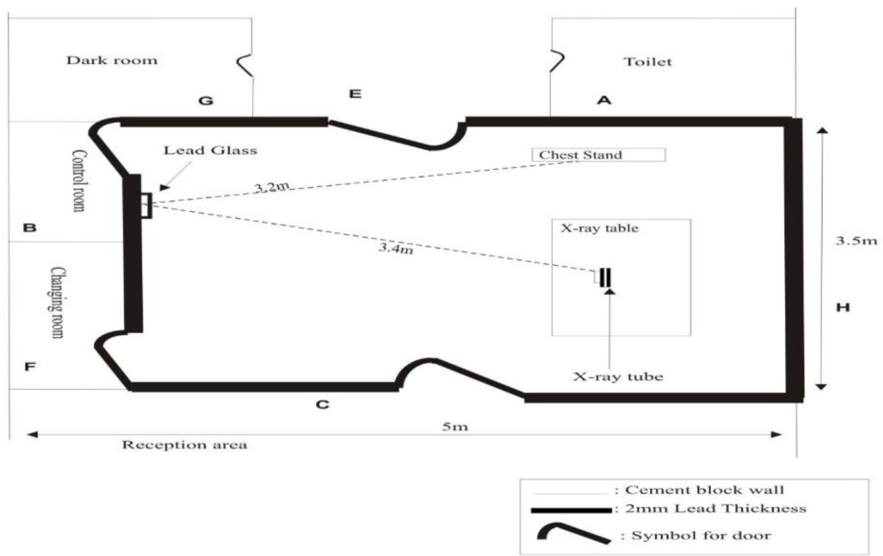

Fig 1: Main radiology building complex, Federal medical center, Katsina (Room I)

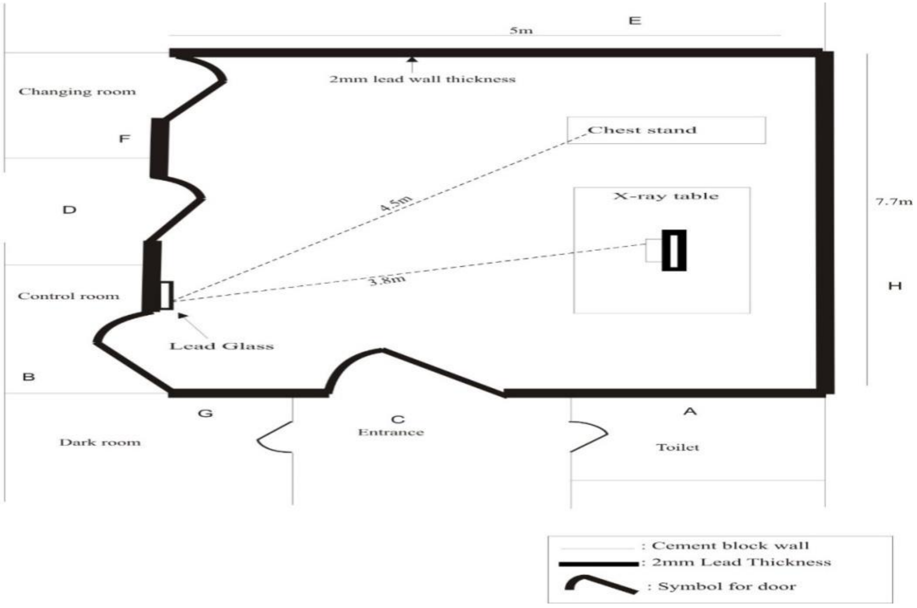

Fig 2: Main radiology building complex, Federal medical center, Katsina (Room II)

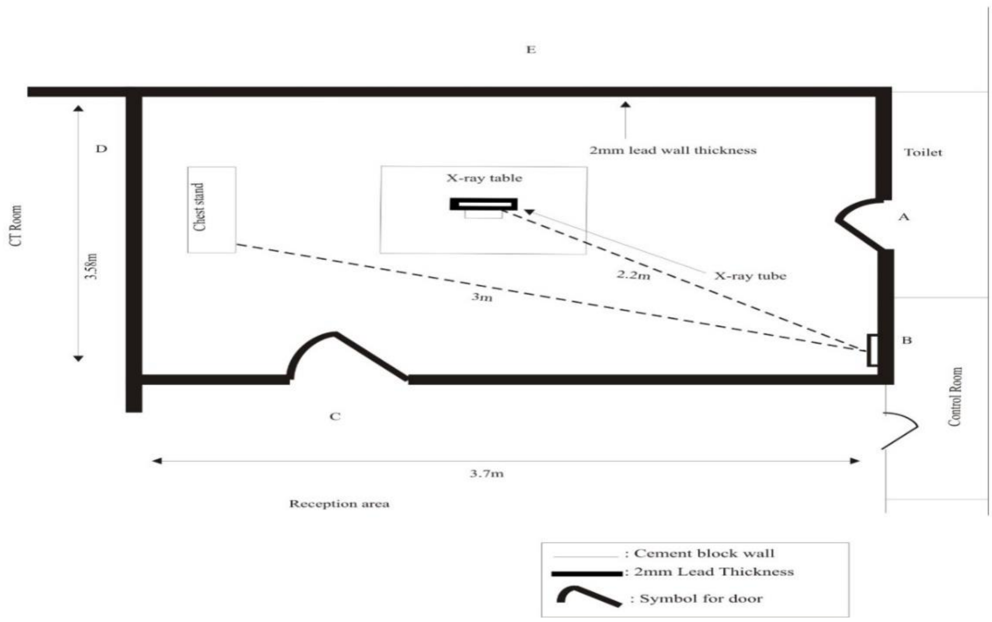

Fig 3: Accident and emergency radiology department, Federal medical center, Katsina (Room III)

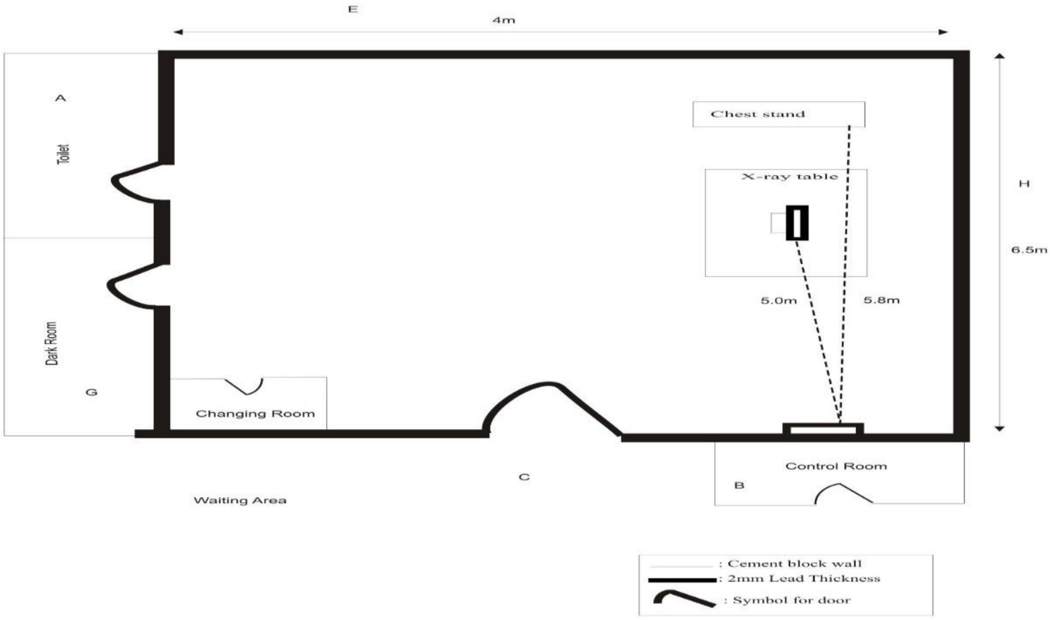

Fig 4: Radiology department x-ray room General Amadi Rimi Specialist Hospital (Room IV)

Table 2 Measurement used to calculate the barrier thickness of room 1 in Federal Medical Centre Katsina.

Position (Room 1)	Type of barrier	Distance (m)	Occupancy factor	Design goal Limit (mGy)
Wall 1	Secondary	1.66	1	0.02
Wall 2	Secondary	1.63	1	0.02
Wall 3	Primary	2.65	1	0.02
Wall 4	Secondary	3.37	1	0.10

Table 3 Measurement used to calculate the barrier thickness of room II in Federal Medical Centre Katsina.

Position (Room II)	Type of barrier	Distance (m)	Occupancy factor	Design goal Limit (mGy)
Wall 1	Secondary	4.10	1	0.02
Wall 2	Secondary	2.17	1	0.02
Wall 3	Primary	3.54	1	0.02
Wall 4	Secondary	3.07	1	0.1

Table 4 Measurement used to calculate the barrier thickness of room III in Federal Medical Centre Katsina.

Position (Room III)	Type of barrier	Distance (m)	Occupancy factor	Design goal Limit (mGy)
Wall 1	Secondary	2.41	1	0.02
Wall 2	Secondary	1.26	1	0.10
Wall 3	Secondary	1.17	1	0.02
Wall 4	Primary	3.21	1	0.02

Table 5 Measurement used to calculate the barrier thickness of room IV General Amadi Rimi Specialist Hospital Batagarawa.

Position (Room IV)	Type of barrier	Distance (m)	Occupancy factor	Design goal Limit (mGy)
Wall 1	Secondary	4.01	1	0.10
Wall 2	Secondary	1.54	1	0.02
Wall 3	Primary	2.44	1	0.02
Wall 4	Secondary	3.74	1	0.02

Table 6: Current and calculated barrier thickness for room 1in Federal Medical Centre Katsina.

Position (Room 1)	Type of barrier	Distance from the X-ray tube (m)	Amount of radiation (*m*Gy)	Calculated barrier thickness (mm) of lead	Current barrier thickness (mm) of lead	Ratio of calculated to current barrier thickness
Wall 1	Secondary	1.66	1814.49	0.620	2.0	0.265
Wall 2	Secondary	1.63	1881.89	0.630	2.0	0.275
Wall 3	Primary	2.65	711.99	0.596	2.0	0.295
Wall 4	Secondary	3.37	88.05	0.075	2.0	0.040

Number of patient = 100 / week

Table 7: Current and calculated barrier thickness for room IIin Federal Medical Centre Katsina.

Position (Room II)	Type of barrier	Distance from the X-ray tube (m)	Amount of radiation (*m*Gy)	Calculated barrier thickness (mm) of lead	Current barrier thickness (mm) of lead	Ratio of calculated to current barrier thickness
Wall 1	Secondary	4.10	297.44	0.220	2.0	0.120
Wall 2	Secondary	2.17	1061.82	0.479	2.0	0.240
Wall 3	Primary	3.54	399.04	0.463	2.0	0.230
Wall 4	Secondary	3.07	106.10	0.088	2.0	0.040

Number of patient = 100 / week

Table 8: Current and calculated barrier thickness for room IIIin Federal Medical Centre Katsina.

Position (Room III)	Type of barrier	Distance from the X-ray tube (m)	Amount of radiation (*m*Gy)	Calculated barrier thickness (mm) of lead	Current barrier thickness (mm) of lead	Ratio of calculated to current barrier thickness
Wall 1	Secondary	2.41	430.66	0.284	2.0	0.135
Wall 2	Secondary	1.26	316.14	0.229	2.0	0.125
Wall 3	Secondary	1.17	1824.82	0.621	2.0	0.315
Wall 4	Primary	3.21	242.60	0.362	2.0	0.180

Number of patient = 50 / week

Table 9: Current and calculated barrier thickness for room IV in General AmadiRimi Specialist Hospital Batagarawa.

Position (Room IV)	Type of barrier	Distance from the X-ray tube (m)	Amount of radiation (mGy)	Calculated barrier thickness (mm) of lead	Current barrier thickness (mm) of lead	Ratio of calculated to current barrier thickness
Wall 1	Secondary	4.01	31.10	0.003	2.0	0.020
Wall 2	Secondary	1.54	1054.85	0.478	2.0	0.240
Wall 3	Primary	2.44	419.82	0.474	2.0	0.240
Wall 4	Secondary	3.74	178.70	0.147	2.0	0.085

Number of patient = 50 / week

DISCUSSION

The dimension of the X-ray rooms in Federal Medical Center for room I, room II and room III are 17.5 m^2, 39.52 m^2 and 13.32 m^2 respectively. Only room I and room II in the facility meet the recommendation of Nigeria Nuclear Regulatory Authority (NNRA) of at least 16 m^2 (NSRP, 2006, No. 19). The room area of room IV in General Amadi Rimi specialist hospital is 34.45 m^2 which equally meet the recommendation of Nigeria Nuclear Regulatory Authority (NNRA).The implication of the above measurement is that room I, room II and roomIV suggest effective radiation protection to the controlled area (control room) and uncontrolled area. The measurement in room III suggests poor radiation protection to the controlled area (control room) and uncontrolled area. This implies that more radiation would reach the control room in room III, which may result to higher radiation level in the control room to exceed maximum permissible level of 0.1 mGy/wk.

Table 6, 7, 8 and 9 shows the result of the calculated barrier thickness and ratio of calculated barrier thickness to current barrier thickness of room I, room II, room III and room IV respectively. The calculated barrier thickness of the walls in each room varies from 0.08 mm to 0.59 mm for room I, 0.08 mm to 0.48 mm for room II, 0.25 mm to 0.63 mm for room III and 0.04 mm to 0.48 mm for room IV. This result is similar to that of the studies conducted by Yusuf *et al*. (2012) at Air Force Military Hospital, Jos and Muhammed *et al.* (2020). The ratios of the calculated to the current barrier thickness of the walls in all the rooms in this study are less than one (< 1). This result is supported by Muhammed *et al*. (2020) and Abubakar and Sidi (2019) but contradicted the findings of Yusuf *et al.* (2012) and Anikoh *et al*. (2009). The contradiction occurs because their study area was poorly shielded.

CONCLUSION

The shielding design parameter (thickness) studied at the Federal Medical Center, Katsina and General Amadi Rimi Specialist Hospital, Katsina were calculated using the $\frac{NT}{Pd^2}$model for diagnostic X-ray shielding in NCRP Report No 147. The shielding parameter (thickness) is within the recommended safety limit specified by the National Council on Radiation Protection and Measurement (NCRP). The ratio of the calculated to the current barrier thickness is less than one (<1). 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.

REFERENCES

Ahmed F., Mkhaibe R., and AbdulraheemDheya A., (2018), Experimental study of some shielding parameters for composite shields, *IOP Conf. Series: Journal of Physics:* Conf. Series 1003 (2018) 012109 doi :10.1088/1742-6596/1003/1/012109

Abubakar A., and Sidi M, (2019), Determination of X-ray shielding thickness in two tertiary hospitals in Kano metropolis, Nigeria. *West AfrJor. Radiol* 2019;26:90-3

Anikoh, S. O., Nuhu, H., Mangset, W. E., Sirisena, U. A., and Mallam, S. P. (2015). Optimization of Radiation protection in Diagnostic Radiology in Jos University Teaching Hospital Shielding Evaluation. *African Journal of Natural sciences (AJNS)*. 12(3), 1119-1104.

Dahinde P., Dapke G., Raut S., Bhosale R. and Pravina P., (2018), Analysis of half value layer (HVL) and tenth value layer (TVL) and mean free path (MFP) of some oxides in the energy range of 122 KeV to 1330 KeV (10.32606/IJSR.V9.I2.00014/*Indian J.Sci.Res.* 09 (2): 79-84, 2019) https://www.researchgate.net/publication/330891500.

Esien-Umo E., Mallam P., Akpa C. and Ukpong E., (2013), X-Ray Barrier Estimation – A Case Study of the General Radiography Room of a Major Nigerian Teaching Hospital, V./*Journal of Association of Radiographers of Nigeria,* Vol. 27, No. I (2013) 16 – 24.\

Health Physics Society,HPS (2021) Radiation Exposure from medical examinations and procedures [online], reviewed 2021. Available at https://hps.org/documents/Medical_Exposures_Fact_sheet.pdf

International Commission on Radiological Protection (ICRP) (2005). Draft; recommendations of the International Commission on Radiological Protection, Sweden

Joseph D., Ibeanu I., Zakari Y., and Joseph Z., (2017).Radiographic Room Design and Layout for Radiation Protection in Some Radio-Diagnostic Facilities in Katsina State, Nigeria. *Journal of the Association of Radiographers of Nigeria*, Volume 31, Issue 1, November 2017

Muhammad B., Sani U., Usman A., and Joseph D., (2020). Evaluation of shielding Barrier of a computer Tomography unit. *FUDMA Journal of Sciences (FJS)* Vol. 4 No. 1, March, 2020, pp 150 – 155.

NEA (1994). Nuclear Energy Agency. An analysis of principal nuclear issues (1994). https://www.oecd-nea.org/brief/brief-10.html.

NSRP (2006). Nuclear Safety and Radiation Protection Act No. 19). Nigerian Radiation safety in Diagnostic and International Radiology Regulations

Vishwanath P., and Badiger N., (2014), Investigation of Gamma and Neutron Shielding Parameters for Borate Glasses Containing NiO and PbO, (Hindawi Publishing Corporation Physics Research International Volume 2014, Article ID 954958, http://dx.doi.org/10.1155/2014/954958)

Yusuf S., Ike E., and Saidu A., (2012). X-rayBarr And Structural Shielding Evaluation in Diagnostic Radiology Department of Air Force Military Hospital, Jos. *International Journal of Advancement in Physics,* Volume 4, Number 1, 2012