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Evaluation of Shielding Thickness at the X-Ray Facilities of General Hospital, Adikpo and General Hospital, Katsina-Ala, Benue State, Nigeria

Samuel Terhemba Kungur
Department of Physics, College of Education, Katsina-Ala
Email address: kungursamuel247@gmail.com

***Abstract**—Evaluation of Shielding Thickness at the X-Ray facilities of General Hospital, Adikpo and General Hospital, Katsina-Ala, Benue State, Nigeria was carried out using a high precision BR-6 Geiger counter radiation detector. The BR-6 Geiger counter radiation detector is a health and safety instrument that is operated to detect low levels of radiation and is designed to measure ionising radiation such as alpha (α), beta particles (β), gamma rays (γ), and X-ray radiation. The workload of 124mA-min/week and use factor of 0.58 and 125mA-min/week and a use factor of 0.36 of the x-ray machine were used to estimate the shielding parameters at 150kVp operating potential.Calculations for the primary shielding in both Centres, showed that the exposure/week without shielding at a point 0.3m after the primary/secondary protective barriers yielded 0.15mR/week and 0.16mR/week for both primary and secondary barriers respectively which is less than the recommended value of 2mR/week. Also, the wall thicknesses at both Centres were measured to be 320mm and 310mm respectively. These values are considered small compared to the estimated attenuation in concrete of x-ray generated at 50 to 300 kVp.*

***Keywords**—Radiation Release, Radiographic X-ray room, Shielding thickness, Radiation Outflow, Unsafe Radiation.*

I. Introduction

Radiation shielding refers to the use of different materials that can reduce or attenuate the number of incoming photons and their energy as it passes through matter.In radiography, an X-ray beam is passed through a portion of the body and the image is projected onto a receptor. The beam that emerges from the body varies in intensity (Ukerun-Akpesiri. et al, 2023). This variation in intensity is caused by attenuation of X-rays in the body. .Materials, such as lead, concrete, alloys, and polymers, are designed to absorb or attenuate most of the radiation, thereby protecting humans and the environment from the harmful effects of radiation (Mokobia et al, 2022).

In recent times, X-rays have become an important part of medicine where it is used for both diagnostic and therapeutic purpose- diseased or health conditions are identified and are treated or managed through therapy (Abba and Sani, 2023). Most hospitals in our society today use X-rays and it is the most frequently used ionizing radiation in medicine; exposure to ionizing radiation can cause cancer and other health challenges (Oluwafisoye et al., 2010). Now, cancer is found to be a major public health problem throughout the universe and it is found to be the second leading cause of death in the United States of America(Rebecca, et al., 2023).

In almost all hospitals that offer X-ray services today, radiologists, caregivers and othermedicine technicians, have an increased risk of exposure to radiation than other hospital healthcare professionals (Inoue et al., 2020). The National Council on Radiation Protection and Measurements (NCRP) provides the widely accepted methodology for radiation shielding design, which has been reviewed and the new recommendations are contained in NCRP, (2015).

Several works have been carried out by different researchers on the evaluation of shielding thickness of medical facilities (Omojola et al., 2021; Agba et al. 2011; Joseph et al, 2017 and Abubakar and Sidi, 2019).

This work is basically aimed at complimenting the works of several other researchers on the evaluation of shielding thickness at the X-ray units of General Hospital, Adikpo and General Hospital, Katsina-Ala, Benue State with a view to determining the adequacy or otherwise of primary and secondary protective shielding of X-ray rooms based on NCRP (2015) recommendation.

II. Material(s) and Method(s)

The study was conducted in two (2) X-ray facilities located in Adikpo and Katsina-Ala towns of zone A senatorial district of Benue State. The facilities were denoted as Centre 1 and Centre 2.

A high precision BR-6 Geiger counter radiation detector was used for radiation measurements.The BR-6 Geiger counter radiation detector is a health and safety instrument that is operated to detect low levels of radiation and is designed to measure ionising radiation such as alpha (α), beta particles (β), gamma rays (γ), and X-ray radiation. Also, a Liangjin 7.5m/25ft long measuring tape was used to measure the dimensions of the centres and other necessary parameters. The x-ray machines in both Centres were the static three (3) phase conventional x-ray machines.

The BR-6 Geiger counter radiation detector and measuring tape, 7.5m long were used for measurement of radiation at 1m from source in the two Centres.

The following formulae were used to estimate the exposure and shielding parameters:

$$W = \frac{No.of patients}{day} \times \frac{No.of films}{patient} \times \frac{mAs}{film} \times \frac{1}{60min/sec} \times \text{No. of days/week} \quad (1)$$

Where W is the workload in (mA-min/wk)

Also,

$$\text{X-ray tube output (K)} = \frac{X\ (mR)}{mAs} \quad (2)$$

Where X is the exposure rate in mR (miliRontgent)

Also, the exposure per week contributed by the primary exposure (X_p), scatter exposure (X_s) and the leakage exposure (X_l) was computed using the equations (Bushberg et al., 2002).

Xp (mR/wk)1m = W (mA min/wk) × K (mR/mA-min) (3)

Where X_p is the primary exposure, W is the workload and K is the tube output

The incident exposure at 1m X_p^1, is corrected for distance to the scattered, $d_{sec.}$ as;

$$X_p^2 = \frac{Xp}{d_{sca}^2} \quad (4)$$

Where X_p is the primary exposure, d_{sca}^2 is the scattered distance and X_p^2 is the incident exposure.

The scatter exposure per week, Xs, at a distance of 1m from the scattering source (patient) was calculated as;

$$Xs \text{ (mR/week) 1m} = X_p^1 \times S \times \frac{(\text{field size}(\text{cm}^2)}{400\text{cm}^2} \quad (5)$$

Where S is the scattered fraction, X_p^1 is the incidence exposure and X_s is the scattered exposure in mR/week.

X_L (mR/week) = 1.67mR / (mA max-min) × W (mA-min / week) (6)

Where 1.67 mR/ (mA max-min) is the maximal leakage radiation, and W is the workload in (mA-min/week).

The division of Xp, Xs and X_L by d_{pri}, d_{sec} and d_{leak}respectively yielded the exposure levels beyond the wall.

The total weekly exposure X, without shielding at a point beyond the wall outside the X-ray rooms was calculated using the equation given by Bushberg et al., (2002);

$$X \text{ (mR / week)} = \frac{Xp}{d_{pri}^2} \times U_{pri} + \frac{Xs}{d_{sec}^2} + \frac{Xl}{d_{leak}^2} \quad (7)$$

Where X_p is the primary exposure, d_{pri}^2 is the primary distance, U_{pri} is the primary use factor; Xs is the scattered exposure and d_{sec}^2 is the secondary distance. X_l is the leakage exposure and d_{leak}^2 is the leakage distance.

The background radiation was taken to determine if there was any environmental factor that could influence the measurements.

III. RESULTS

The experimental results were obtained after a detailed computation carried out from the measured radiographic parameters/shielding distances at the Centres. These results are presented in tables 1 to 8.

TABLE 1. Radiological Parameters measurements obtained at Centre 1

Parameters	Parametric values
Tube voltage (kVp)	150
Exposure rate (mR/hr)	0.25
Maximum Exposure time (s)	0.370
Mas	100
Field size (cm^2)	1350

TABLE 2. Radiological Parameters measurements obtained at Centre 2

Parameters	Parametric values
Tube voltage (kVp)	150
Exposure rate (mR/hr)	0.20
Maximum Exposure time (s)	0.375
Mas	100
Field size (cm^2)	1352

TABLE 3. Measured Shielding Distances at Centre 1

Measured Distances	Parametric values
Primary distance, d_m (m)	2.55
Secondary distance, d_{sec} (m)	0.96
Scattered distance, d_{sca} (m)	1.36
Leakage distance, d_{leak} (m)	2.30
Source to image distance, SID (m)	1.56
Film to coat distance (m)	0.38
Wall thickness	0.31

TABLE 4. Measured Shielding Distances at Centre 2

Measured Distances	Parametric values
Primary distance, d_m (m)	2.54
Secondary distance, d_{sec} (m)	0.97
Scattered distance, d_{sca} (m)	1.37
Leakage distance, d_{leak} (m)	2.32
Source to image distance, SID (m)	1.57
Film to coat distance (m)	0.36
Wall thickness	0.32

TABLE 5. Computed Exposure levels at Centre 1

Computed Exposures	Parametric values
Primary exposure, Xp (mR/h)	1.50×10^{-5}
Incident exposure, X_p^1, (mR/wk)	8.00×10^{-4}
Scattered exposure, X (mR/wk)	4.08×10^{-6}
Tube leakage, X_1 (mR/wk)	0.74

TABLE 6. Computed Exposure levels at Centre 2

Computed Exposures	Parametric values
Primary exposure, Xp (mR/h)	1.54×10^{-5}
Incident exposure, X_p^1, (mR/wk)	8.04×10^{-4}
Scattered exposure, X (mR/wk)	4.06×10^{-6}
Tube leakage, X_1 (mR/wk)	0.76

TABLE 7. Shielding Parameters obtained at Centre 1

Shielding parameters	Parametric values
Tube woakload (mA-min/wk	124
X-ray tube output, K at 1m from the source (mR/mA-min)	1.24×10^{-5}
Use factor	0.58
Occupancy factor	1
Exposure towards primary barrier (mR/wk)	0.15
Exposure towards secondary barrier (mR/wk)	0.15
Required primary shielding barrier of concrete thickness (mm)	3.94
Required secondary shielding barrier of concrete thickness (mm)	3.94

TABLE 8. Shielding Parameters obtained at Centre 2

Shielding parameters	Parametric values
Tube woakload (mA-min/wk	125
X-ray tube output, K at 1m from the source (mR/mA-min)	1.25×10^{-5}
Use factor	0.56
Occupancy factor	1
Exposure towards primary barrier (mR/wk)	0.16
Exposure towards secondary barrier (mR/wk)	0.16
Required primary shielding barrier of concrete thickness (mm)	3.96
Required secondary shielding barrier of concrete thickness (mm)	3.96

TABLE 9. Compared results of workload and use factor from different researches

Parameter	Current research		Gemanam et al, 2017	Esien-Umo, 2007	Okunade & Awodele, 2001	Agba et al, 2011
	Centre 1	Centre 2				
Workload (mA-min/wk)	124	125	125	138,20	95.22	60
Use factor	0.58	0.56	0.56	0.68	0.43 – 0.73	0.50

IV. Discussion

The radiographic parameters measured and the shielding distances that were obtained after a careful computational work showed that the facility; Centre 1 has workload of124mA-min/week and Centre 2 has a workload of 125mA-min/week. These values fall within the range of 100mA-min/week – 1000mA-min/week for a radiographic facility that is less busy and a very busy one respectively as recommended (NCRP, 2015). The result also lied between the workload ranges of 73mA-min/week to 530mA-min/week for facilities of orthopaedic nature as recommended (Bushong and Glaze, 1983).

In table 9, a relative comparison of the workload obtained at Centre 1 and Centre 2 with results of Gemanam et al. (2017), carried out at the Benue State University Teaching Hospital, Makurdi, and those of Agba et al, 2011,carried out at the Federal Medical Centre, Makurdi, Esien-Umo, 2007, carried out at Ahmadu Bello University Teaching Hospital, Zaria, and Okunade and Awodele, 2001, carried out at University Teaching Hospital, Ibadan and the recommendations of NCRP, 49. Based on the figures in table 9, this research is within the framework of other researches as compared and is consistent with other works.

Calculations for the primary shielding in both Centres, showed that the exposure/week without shielding at a point 0.3m after the primary/secondary protective barriers yielded 0.15mR/week and 0.16mR/week for both primary and secondary barriers respectively. These are less than the recommended value of 2mR/week (Bushberg, et al 2002).

Furthermore, the wall thicknesses at both Centres were measured to be 320mm and 310mm respectively. These values are considered small compared to the estimated attenuation in concrete of x-ray generated at 50 to 300 kVp.

V. Conclusion

The estimated shielding parameters at both Centres conform to the recommended maximum limits of NCRP, 49 and 151.

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