SHIELDING EVALUATION OF RADIOLOGY DEPARTMENTS OF SELECTED HOSPITALS IN NIGERIA.

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ABSTRACT
In medical institution where there is x-ray installation, the general public, patients, and medical staff that carry out radiography procedures are likely to receive significant radiation doses to their hands and other parts of their bodies not covered with protective equipment. The radiation doses received, overtime will gradually affect the cells and organs of their bodies thereby causing unforeseen ailments. An evaluation of the shielding barrier in two selected hospitals were carried out for the general radiography rooms. The ratio of the calculated to the design shielded barrier thickness indicated that the areas less than or equal to one have adequate shielding barrier and are within the recommended level. Those areas greater than one are above the recommended level, which may require re-enforcement in case of increase in workload in the nearest future. The results calculated and that of the design shielded barrier thickness were obtained. For hospital A, Console Room 1 (0.0408), Console Room 2 (0.1993), Toilet (0.7010), Darkroom (0.0940), Changing Room 1 (0.0544), Changing Room 2 (0.2053) Door 1 (1.1326) and Door 2 (3.7857). For hospital B changing room (4.0714), Console (0.204) Door (0.000), Shelf (1.9081) and reception (0.520). The shielding barrier thickness calculated from the XRAYBARR was compared with design dose limit and the design shielding barriers thickness of some areas were found to be unsafe for hospitals A and B. This implies that the patients, staff, and the general public stand a great risk of health hazard. Hence an effective quality Assessment program should be put in place.

Keywords: Shielding design, Radiation, Hospitals.

INTRODUCTION

Environmental and occupational safety has become a thing of concern in every country all over the world. However various measures have been deployed through research to proffer solutions either for identification, total elimination, minimization or control of such hazards in the radiology departments of health institutions, so as to minimize radiation on workers, patients and the public. Over the years, x-rays has become an important tool in medical diagnosis and therapy, most medical decisions are dependent on x-ray and early diagnosis of some diseases depend completely on x-ray examinations (Braestrup & Vikerlof, 1974). X-ray has maintained a key role in diagnosis of diseases, injury and in x-ray therapy (Oluwafisoye, Olowookere, Jibrio, Alausa & Efunwde, 2010). However the potential hazards that may result from the use of x-ray facilities should not be neglected because if the x-ray facilities are not properly shielded and allowed to interact with intended parts of the body, they can pose potential hazard to patients, workers and members of public. (International Commission on Radiation Protection (ICRP), 1991; International Atomic Energy Agency (IAEA), 1996). There are proven means of radiation protection, comprising the use of time, distance and shielding. Reduction of the exposure time, increasing distance from source and shielding of patients and occupational workers have proven to be of great importance in protecting patients, personnel and members of the public from the potential risk of radiation (Seeram & Travis, 1997; Atomic Energy Regulation Board (AERB), 2005). In other words, radiation optimization is applied to concepts, requirements, technologies and operations related to the protection of people, against the harmful effects of ionizing radiation. Optimization practices are aimed simply at keeping all radiation risks to health as low as reasonably achievable with adequate image quality, social and economic consideration being taken into account under the constraint that no individual will be subjected to undue risk (IAEA, 1989).

MATERIALS AND METHODS

The following materials were used for the study: X-ray facilities: X-ray machines of the two hospitals were used for the study. Plate 1 shows one of those x-ray machines. They were all installed already, some were in a fixed position others were portable, hand-held and mobile x-ray machines. Measuring tape: it I was used for measuring the distances from the x- ray machine to the consoles, windows, doors and toilets in the radiographic rooms of these hospitals. The distance from the x-ray machines in the radiographic room was measured using the measuring tape.

Micro –screw gauge: It was used to measure the thickness of the shielding materials used in the radiographic rooms of these hospitals. The micro – meter screw gauge was used to measure the thickness of lead already in place.

Xraybarr software: This software was used to evaluate the shielding barriers used in the radiographic rooms of these selected hospitals.

Workload Determination

The accurate value of workload is required to have accurate shielding. So, the exposure techniques for all patients were recorded by radiography staff for eight (8) weeks in these selected diagnostic hospitals. However, to calculate workload for each patient, the number of exposures and techniques including mAs and kVp were recorded. Also, the number of repeated examinations was included in the calculations.

Using the collected data, the mean workload in terms of mA minwk^{-1} was calculated using (El-khatuib., Ervin & Choran, 1987)

$$B = \frac{Pd^2}{WUT} \tag{1}$$

Where B is the transmission build factor, P is the maximum permissible dose (currently named

dose limit) according to NCRP 49, W is the workload, U is the use factor, T is the occupancy factor, d is the distance from focal spot to the occupied area.

when the x-ray beam is not aimed at a particular barrier, scattered radiation will reach that barrier. The amount of the scattered radiation depends on the radiation energy, x-ray field size, distance from the scatterer, and the scattering angel. The scattered radiation level is:

$$\frac{B_s = P(d_{sca})^2 \cdot (d_{sec})^2\ 400}{aWTF} \tag{2}$$

Where B is the transmission build factor B_s denote secondary build transmission factor . P is the maximum permissible dose (currently named dose limit) according to NCRP 49, W is the workload, U is the use factor, T is the occupancy factor, d_{sec} is the secondary scatter, d_{sca} is the primary scatter,F denotes field size in terms of centimeter and is the fractional scatter at lm from the scatterer, a is the ratio of scattered to incident intensity.calculations. The required thickness of a primary barrier was calculated using (El-khatuib., Ervin., & Choran, 1987)

$$\text{Required thickness} = NT/Pd^2 \qquad (3)$$

Where N is the total number of patients per week, T represents occupancy factor, P is design goal (mGy/wk), d is the distance to occupied area (m).

Estimation of Shielding Barrier

The program, XRAYBARR was used to calculate the thickness of barrier required to shield the diagnostic x-ray installations. With the annual dose limit (P) and occupancy factor (T) of the area to be shielded specified, the program uses the workload in the room, user factor, distances to the occupied area and the x-ray tube information to calculate the barrier thickness required. This reduces the total annual dose to P/T. (Annual dose limit over Occupancy factor).The XRAYBARR. After imputing the type of barrier and x-ray tube information and clicking the calculate button, the program presents the required minimum shielding thickness in (mm and inches) and the details of the calculated unshielded and shielded primary, scattered and leakage dose generated by the x- ray tube. The program is used to calculate the unshielded and shielded primary, scatter (Fig 1). It also gives the leakage radiation and the thickness of the barrier required in (mm or inches) of lead, concrete and wood.

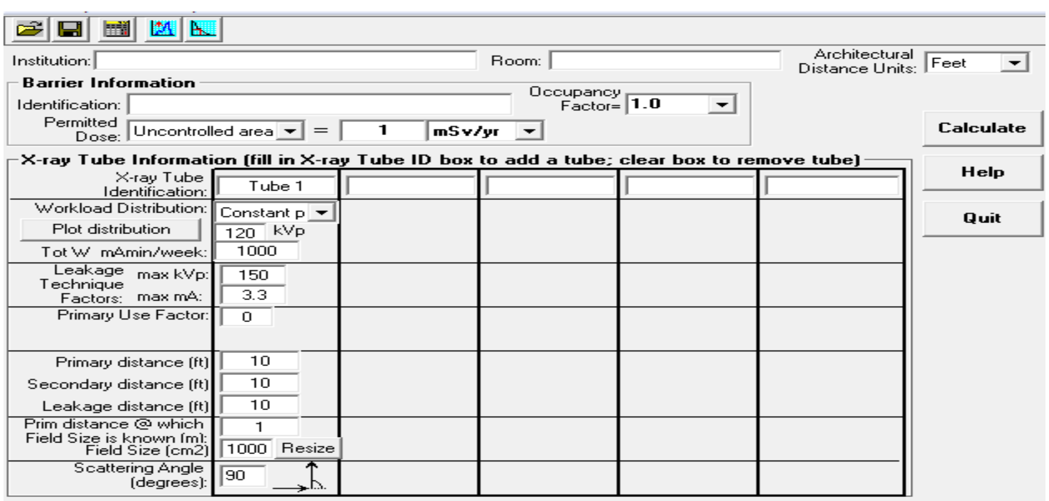

Figure 1: XRAYBARR Calculation Model

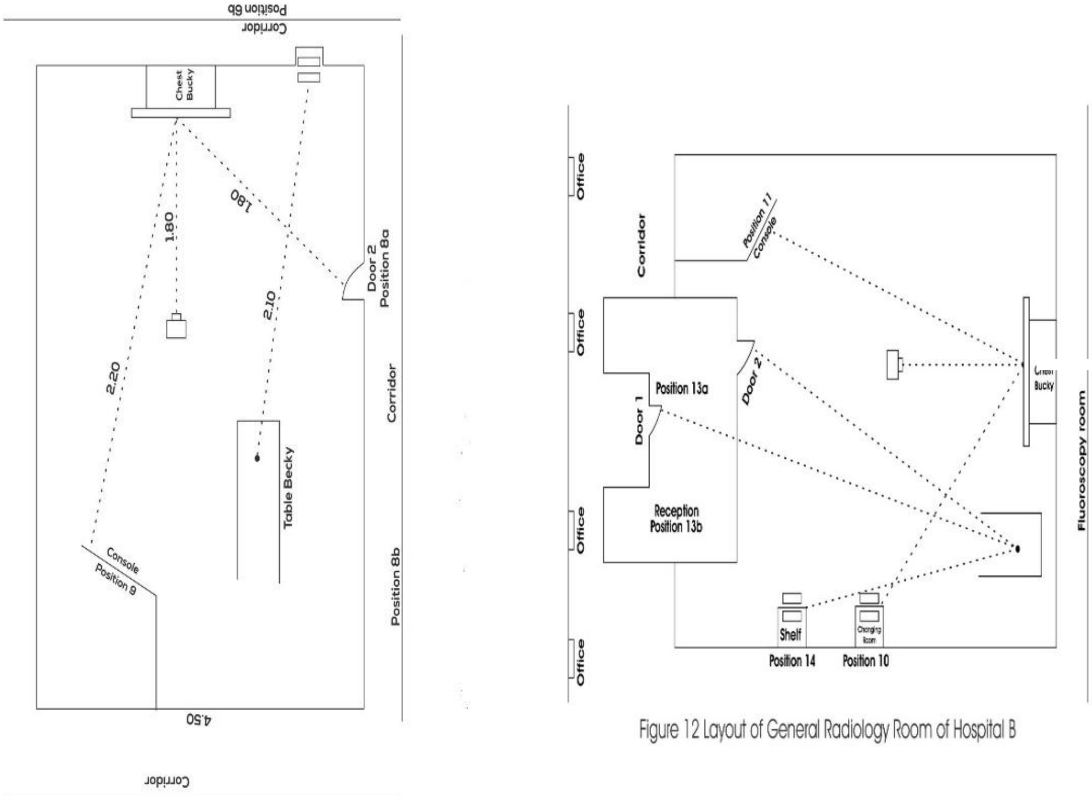

Figure 2 layout of General Radiology room of hospital A and B

RESULTS AND DISCUSSION

Table 1 shows the results of the workload calculated using each parameter applicable to each x-ray room and x-ray machine installed in hospitals A and B. Table 1 is the Total Workload Distribution in the General Radiography Room in hospitals A and B The result of the research was determined, by estimating the workload of these selected hospitals to know if they are lower or higher than the workload recommended by NCRP 147. The total workload distributions are for the chest walls (Erect Bucky) and floor/other barrier (X-ray table) workload distributions. The total workload for all barrier distributions provides a more accurate description of the intensity and penetrating ability of radiation directed at primary barriers and it is used for primary barriers calculations (NCRP, 2005). In the general radiography rooms of hospitals A and B the workload distribution occurs between 60kVp to 100kVp. The Rad room (all barriers) consists of exposures in a general radiography room containing a Chest Bucky and radiography table. It is composed of the sum of Rad Room Bucky (Chest Bucky) and Rad Room (floor/other barriers) workload distribution is used for secondary barrier shielding calculations, (NCRP, 2005).

Table 1. Total Workload Distribution in the General Radiography Room of Hospital A & B

X – ray Room	Average patients per week (N)	Workload mA – Min/week 60Kvp – 100Kvp > 100Kvp
General radiography room		
Hospital A	200	30.20
Hospital B	380	35.00

Estimation of Shielding Barrier for Hospital A X-ray Room

The Chest Bucky protects against secondary radiation from the erect Bucky and x-ray table. The shielding barrier at position 3 (Console) protects the radiographer behind the console against secondary radiation from the erect bucky and x-ray table, so the sum of the workload of the two distribution was used to determine the shielding barrier thickness at the position 4 (Changing room). The door protects against primary radiation from cross table lateral and secondary radiation from the erect bucky and x-ray table, the sum of the two workloads was used in calculating the thickness of these shielding barriers. This shows that the primary radiation beam is also the major contributor to the x-ray room. The door 1, door 2 and the door for rooms 1 and 2 are all considered as unshielded areas while Console, Changing rooms, darkroom, and toilet are considered as controlled areas. The thickness of shielding barrier required to protect the occupied area beyond these positions increases with decreasing distances for the same occupancy factor. It can be seen from the table that for the same workload and use factor greater the occupancy factor, the thicker the shielding barrier required at these positions. Distance always plays an important role, the smaller the distance, the greater amount of radiation produced at these points and the thicker the thickness at these positions. In the general radiography room of hospital A the shielding barrier thickness required at the different positions to the design dose limit of 0.02mSv/week for uncontrolled areas ranges from 0.689mm of lead equivalent to 7.480mm of concrete and 127.000 mm of wood at position 6 (Toilet). Also, 0.111mm of lead, 11.500mm of concrete, and 180.000mm of wood was required at position 1 (Door I). There was 0.3708mm of lead 34.08mm of concrete, and 399.6mm of wood at position 2 (Door 2), while the required lead shielding to reduce the unshielded radiation dose to the design limit of 0.1mSv/week for controlled areas ranges from 18.700mm of concrete, and 116.00mm of wood at position 3 (Console). 0.141mm of lead equivalent to 14.33mm of concrete, and 213.90mm of wood was placed at position 5 (darkroom). 0.0817mm of lead, 8.730mm of concrete, and 144.30mm of wood at position 4 (Change room) and 0.308mm of lead equivalent to 28.900mm of concrete, and 356.000mm of wood at position 7 (Change room 2). The thickness of concrete already in place in Room 1 and 2 is 0.099mm of lead equivalent to 25.14mm of concrete and 323.400mm of wood as the shielding barrier in the walls of the general radiography room of hospital A while the lead glass at the position 3 (Console) is 1.5mm of lead thick.

Estimation of Shielding Barrier for Hospital B

The results in Table 3 presents the unshielded and shielded dose per week and the thickness of shielding barrier required to reduce these doses to the design doses limit (P) in the general radiography room of hospital B. In this room, the shielding barrier at position 10 (changing room), protects against secondary radiation from the erect bucky and x-ray table, therefore, the sum of the workload of the two distributions was used in calculating the thickness of the shielding barrier. The shielding barrier at position 11 (Console), protects the radiographer behind the console against secondary radiation from the erect bucky and the x-ray table, so the sum of the workload of the two was used to determine the shielding barrier at position 11 (console).The barrier at position 13 (Reception), protects against primary radiation from the erect Bucky and secondary radiation from X-ray table. The barrier at position 12 (Door 1) and position 10 (Changing room), protects against secondary radiation from the x-ray table only. Therefore, the Rad Room (All Barriers) distribution was used to determine the shielding thickness at these positions. . Position 12 (Door 1), position 13 (Reception) are considered as uncontrolled areas while position 11 (Console), and position 10 (Changing room) are considered as controlled areas. The higher the workload (W), the higher the amount of unshielded radiation at these positions. This can be seen at position 11 (Console), position 13 (Reception).The results in table 31 and 32 shows that the primary radiation beam is the major contributor to the unshielded radiation dose inside the x-ray room. Position 12 (Door), position 13 (Reception) are considered as uncontrolled areas while position 11 (console), and position 10 (changing room) are considered as controlled areas.

The shielding barrier thickness required at the different positions to reduce the unshielded radiation dose to the design dose limit of 0.02mSv/week for uncontrolled areas ranges from 0.7795mm of lead equivalent to 66.370mm of concrete, and 624.40mm of wood at position 13 (Reception), to 0.187mm of lead equivalent to 18.400mm of concrete and 25.700mm of wood at position 14 (Shelf). The required lead shielding reduce the unshielded radiation dose to the design limit of 0.1mSv/week for controlled areas ranges from 0.399mm of lead equivalent to 36.400mm of concrete and 417.000mm of wood at position 10 (Console), to 0.408mm of lead equivalent to 37.030 mm of concrete and 421.000mm of wood at position 11 (Console). The shielding barrier already constructed in the walls of the general radiography room of hospital B is 102.70mm of concrete while the glass at the position 11 (Console) is 2.0mm of lead thick.

Table 2. Comparison of the Design dose limit to the measured shielded dose and calculated shielding barrier thickness to the Design Barrier thickness for the General Radiography Room of Hospital A

Position	Measured Shielded dose (mSv/week)	Design dose limit (mSv/week)	Ratio of design dose limit to measured shielded	Design Barrier thickness (mm of lead)	Calculated Barrier thickness (mm of lead)	Ratio of Calculated to design barrier thickness	Type of barrier
1. Console Room 1	0.1000	0.1000	1.000	1.500mm	0.0612	0.0408	Secondary
2. Console Room 2	0.1000	0.1000	1.000	1.500mm	0.2990	0.1993	Secondary
3. Toilet	0.1000	0.02000	0.200	0.098mm	0.0687	0.7010	Secondary
4. Door Room 1	0.0998	0.02000	0.200	0.098mm	0.1110	1.1326	Secondary
5. Door Room 2	0.0999	0.1000	1.000	0.098mm	0.3710	3.7857	Primary
6. Darkroom	0.1000	0.1000	1.000	1.500mm	0.1410	0.0940	Secondary
7. Changing Room 1	0.1000	0.1000	1.000	1.50mm	0.0817	0.0544	Secondary
8. Changing Rm	0.0997	0.1000	1.003	1.50mm	03080	0.2053	S

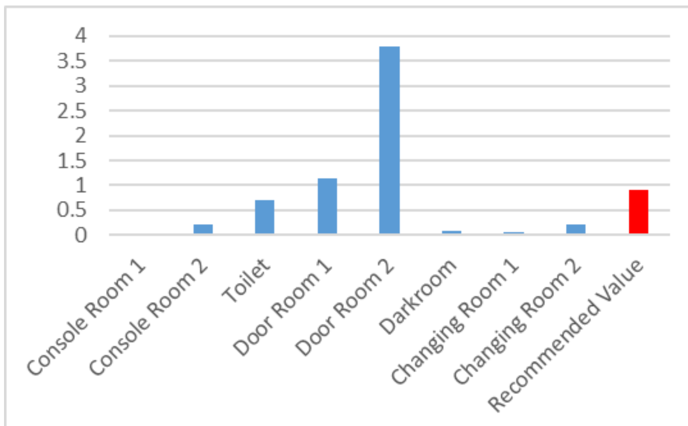

Figure 3 Graph of the ratio of the calculated to the design barrier thickness for hospital A

Table 3. Comparison of the Design dose limit to the measured shielded dose and calculated shielding barrier thickness to the design shielding Barrier thickness for the General Radiography Room of Hospital B

Position	Measured Shielded dose (mSv/week)	Design dose limit (mSv/week)	Ratio of Design thickness measured	Design Barrier Barrier thickness (mm of lead)	Calculated Barrier thickness (mm of lead)	Ratio of Calculated to Design barrier thickness	type of barrier
1. Position	0.1000	0.1000	1.0000	0.098mm	0.399	4.0714	Secondary
2. Changing room	0.1000	0.1000	1.0000	2.00mm	0.408	0.204	Secondary
3. Console	0.06389	0.0200	0.3130	0.098mm	0	0	Secondary
4. Shelf	0.1000	0.0200	0.2000	0.098mm	0.187	1.9081	Primary
5. Reception	0.1000	0.0200	0.2000	1.500mm	0780	0.520	Primary

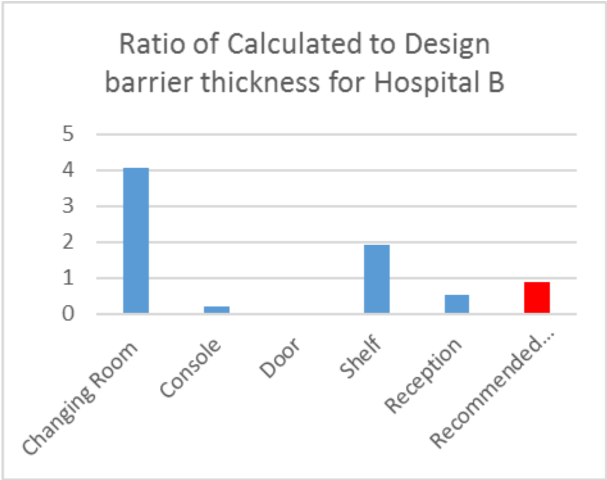

Figure 4. Graph of ratio of the calculated to design barrier thickness for hospital B.

Result of Comparison of Design Dose Limit to the Measured Shielded Dose.

The Tables 2 and 3 presents the comparison of the design dose limit to measured shielded dose and calculated shielding barrier thickness for the radiology departments of hospitals A and B. It can be seen from Table 2 that the ratio of the design to the measured doses was equal to 1 (= 1) for the radiation dose levels beyond the barriers. The radiation dose levels beyond the barriers were lower than the design dose limit (P) of 0.1mSv/week for the controlled areas whereas the ratio of the design to the measured shielding doses were less than 1 (<1) for the uncontrolled areas, indicating that the barriers were greater than the design dose limit (P) of 0.02mSv/week for uncontrolled areas, that is at positions 1 (Door 2), 2 (door 1), 6 (toilet), 6b (corridor) in Hospital A room1 and positions7b (corridor),8a (door), 8b (corridor) in Hospital A room 2 and positions 12 (Door 2), 13 (Door 1), 13b (Reception).The radiation dose levels beyond the shielding barrier with the corresponding design dose limit and the calculated shielding barrier thickness for the general radiography room of Hospital B. The shielding barrier thickness at positions 12 (Door) and 13b (Reception) is not adequate to reduce the uncontrolled radiation dose in the uncontrolled area of Hospital B.

CONCLUSION

The walls of the room housing the x-ray diagnostic equipment of hospital A, Room 1 and 2 were made of 9.0 inches hollow cement blocks, 1.5mm of lead. The doors of different rooms are made with woods of thickness 5cm and the operator Console is made of 2.0mm of lead glass. The Control areas, are the operator's Console, changing room, Darkroom while the other barriers are uncontrolled areas. However this present situation can be tolerated if the barriers at these positions are re-enforced with additional lead shielding and the gaps between the shielding barriers are made to overlap at the joints or the positions can be considered as a controlled area thereby restricting the use of these areas. The calculated values from XRAYBARR show that controlled areas are adequately shielded while the uncontrolled areas are not adequately shielded especially Door 2 of x-ray room in hospital A. In hospital B, the walls of the general radiography room are made of 11.0 inches of the hollow cement blocks, of 2.0mm of lead glass. The operator Console is made of 2.0 mm of lead glass. The controlled areas are the operator's Console, Shelf and Changing room while the rest barriers are uncontrolled areas. The changing room and the shelf need re-enforcement if there is increase in workload, the barriers can be re-enforced with additional lead shielding.

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