Assessment of effectiveness of radiation shielding materials for X-rays facilities in a Federal Teaching Hospital Gombe, Gombe State, Nigeria

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Abstract

The assessment of the effectiveness of minimum radiation shielding barriers for X-rays facilities in a federal teaching Hospital Gombe, Gombe Nigeria**.** This was achieved with the use of rados 200 survey meter to measure scattered radiation exposure at a prescribed distance during radiological examinations. The shielding materials considered in the conventional X-ray machine room in the radiology department of the Federal Teaching Hospital, Gombe, during examination and measurements of exposure were concrete plus lead, wood, wood plus glass respectively. The measurements were carried out by positioning the survey meter at five different points. The result obtained for the concrete plus lead, wood, and wood plus glass shielding barriers ranged from 0.05 ± 0.01 to 0.12 ± 0.01 μSv/hr, 0.08 ± 0.01 to 0.13 ± 0.01 μSv/hr and 0.08 ± 0.01 to 0.15 ± 0.01 μSv/hr respectively. Annual Effective Dose Equivalent (AEDE) values for concrete plus lead, wood, and wood plus glass shielding barriers ranged from 0.2428 to 0.5826 mSv/y, 0.3884 to 0.6472 mSv/y and 0.4044 to 0.7283 mSv/y respectively. All the radiation shielding barriers are all effective with the concrete plus lead barrier being the most effective. Based on the results obtained, the AEDE were within the recommended permissible limit of 1 mSv/y.

Keywords: X-ray, conventional room, survey meter, scattered radiation, equivalent dose, and shielding barriers

1. Introduction

Right from the beginning of man, the human population has been exposed to ionizing radiation from both natural and artificial sources. [1]. These natural sources are categorized as terrestrial, cosmological, and primordial sources; ionizing radiation is produced artificially by industries, medical diagnostic facilities, nuclear research establishments, nuclear reactors, research involving radio-isotopes, and nuclear weapon development facilities;

ionizing radiation has a higher energy than non-ionizing radiation and can thus knock out electrons from atoms; ionizing radiation has a lower energy and cannot do so. Although other nuclear techniques like positron annihilation spectroscopy, neutron scattering, external bremsstrahlung studies, and energy dispersive X-ray fluorescence (using a radio isotope as the source of incident radiation) help researchers to understand materials more elaborately at the basic, microscopic, and even sub-microscopic levels. In the previous few decades, its use has greatly expanded [1]. Indicating that the impacts of radiation have also grown. Other uses, such as those for food preservation, cancer therapy, particle accelerator facilities, and medical X-ray diagnostic equipment, are known to seriously harm their users' health [2].

Shielding is required to protect people and delicate electronic equipment from such ionizing radiation. To protect humans and the environment from the damaging effects of ionizing radiation, radiation shielding entails the construction and use of barriers using suitable shielding materials. It can alternatively be explained as a collision- and atom-based interaction between particles and matter. The parameters that must be taken into account while defining shielding and choosing a material for a shielding wall are the cross-sections of the various isotopes of this material with the associated radiation and the thickness of the shielding wall. A high cross-section indicates significant contact with matter and, as a result, effective shielding. The shielding wall design needs to be thick enough to comply with safety standards and slow down the dose rate [3]. To estimate shielding for x rays, specialized shielding methods have been devised [4].

The effectiveness of filtration is assessed using the X-ray beam's half value layer. To eliminate low-energy (soft) X-ray from the beam, proper filtration is required. A patient's dose will increase if the half-value layer is too low, allowing low energy X-rays to hit them without improving diagnostic information [5]. Due to its use in numerous industries over the past ten years, including radiation protection, hadron therapy, nuclear power plants, etc., radiation shielding materials have attracted increasing interest [6]. Due to their high density and ease of shaping, concretes are among the most often utilized radiation shielding materials against ionizing radiations [7].

A numerical comparison of lead's attenuation and hardening qualities to those of hardware (aluminum and steel) and phantom materials (Lucite, soft tissue, and water). The results demonstrated that the shielding provided by lead attenuation equivalent thicknesses (LAE) and lead hardening equivalent thicknesses (LHE) is not strictly similar to that provided by substitute thicknesses. (Phantom materials, aluminum and steel) The 'precise' LAE that will lower the primary radiation level equally for the patient and radiography table may be greater by close to 20% or more of that which is not exact when there are variances in attenuation and hardening qualities [8].

This incorporation's goal is to lessen the amount of needless ionizing radiation exposure to patients, the general public, and workers whose recommended yearly dose limits are 1 mSv/yr and 20 mSv/yr respectively.

2. Methodology

Using the RADOS 200, a highly calibrated multi-purpose survey meter, the background radiation was measured. The apparatus can detect gamma rays and was calibrated at Ahmadu Bello University in Zaria's Center for Energy Research and Training. Nigeria is described as having a 0.1 calibration factor by the International Atomic Energy Agency [9].

For this study, a conventional x-ray machine room with wood, wood plus glass, and concrete plus lead bunker shielding barriers was used in the radiology department of the Federal Teaching Hospital in Gombe. The amount or dose of radiation emitted by the conventional x-ray machine while they were in use was measured using a survey meter that was properly calibrated. The measuring tape was used to measure the various meters of distance.

2.1 Taking Readings with the Survey meter (Dose Rate Measurement)

1. The survey meter's zero inaccuracy was adjusted in accordance.
2. The survey meter was positioned for this investigation at specific locations known as sampling points, labelled with codes A1–A6, B1–B6, and C1–C6, with regard to the various shielding barriers in the study area, at a height of 1m from the floor at varying distances outside the barriers. 3. At each sampling location, the average reading (mean) was calculated using a total of three readings.

2.2 Calculation of the Standard Deviation to the Mean

The standard deviation from each mean value obtained was estimated using the relation:

$$S.D = \sqrt{\frac{1}{N}\sum_{i=0}^{N}(x_i - \mu)^2}$$

Where: N = number of readings in each instance

X_i = individual values from the survey meter

μ = mean value.

2.3 Calculation of Annual Effective Dose Equivalent (AEDE) in milli-sievert per year (mSv/y)

The annual effective dose was calculated using the mean values extrapolated from three separate exposure rates collected with the survey meter, keeping in mind that all distances are contained within the department.

The annual effective dose (AEDE) was calculated using the formula:

AEDE (mSv/y) = mean dose rate (μSv/hr) × T(h) × OF × CC

Where T = 8670 that is time conversion in hour from year

OF = Occupancy factor given as 0.8 [10].

CC = Conversion coefficient, which is equal to 0.7 for adults

3. Results and Discussion

The findings of the mean ionizing radiation scattered in the surroundings at different distances when the X-ray machine was in operation are provided in Tables 1, 2, and 3 for the different types of shielding barriers within the conventional X-ray unit of the radiology department. The total dose for each table is presented along with the standard deviation for each mean, and the annual effective dose equivalent was also evaluated and reported in each instance. The estimated yearly effective dosage for every person was discovered to be under the advised amount of 1mSv/y.

Table 1: Measured Radiation Dose Rate and AEDE at Various Distances from the Concrete and Lead Bunker

Location Code	Distance from source (m)	Measured values (µSv/hr)			Mean (µSv/hr) ± SD	AEDE (mSv/y)
		1ST	2ND	3RD		
A1	5.00	0.13	0.12	0.11	0.12 ± 0.01	0.5900
A2	7.00	0.13	0.11	0.10	0.11 ± 0.01	0.5009
A3	8.00	0.05	0.06	0.09	0.07 ± 0.02	0.3238
A4	9.00	0.06	0.04	0.09	0.06 ± 0.02	0.3073
A5	10.00	0.03	0.09	0.06	0.06 ± 0.02	0.2913
A6	12.00	0.04	0.06	0.05	0.05 ± 0.01	0.2428

Table 2: Measured Radiation Dose Rate and AEDE at Various Distances from the Wood Shielding Barrier

Location Code	Distance from source (m)	Range of measured values (µSv/hr)			Mean (µSv/hr) ±SD	AEDE (mSv/y)
		1st	2nd	3rd		
B1	5.00	0.15	0.13	0.12	0.13±0.01	0.6472
B2	7.00	0.07	0.11	0.13	0.10±0.03	0.5015
B3	8.00	0.10	0.12	0.11	0.11±0.01	0.5341
B4	9.00	0.11	0.06	0.05	0.07±0.03	0.3559
B5	10.00	0.09	0.08	0.07	0.08±0.01	0.3884
B6	12.00	0.08	0.07	0.09	0.08±0.01	0.3884

Table 3: Measured Radiation Dose Rate and AEDE at Various Distances from the Wood plus Glass Shielding Barrier

Location Code	Distance from source (m)	Range of measured values (µSv/hr)			Mean (µSv/hr) ±SD	AEDE (mSv/y)
		1st	2nd	3rd		
C1	5.00	0.15	0.13	0.16	0.15±0.01	0.7123
C2	7.00	0.15	0.17	0.13	0.15±0.02	0.7283
C3	8.00	0.12	0.12	0.11	0.12±0.01	0.5666
C4	9.00	0.10	0.09	0.08	0.09±0.01	0.4370
C5	10.00	0.09	0.08	0.08	0.08±0.01	0.4044
C6	12.00	0.08	0.09	0.08	0.08±0.01	0.4044

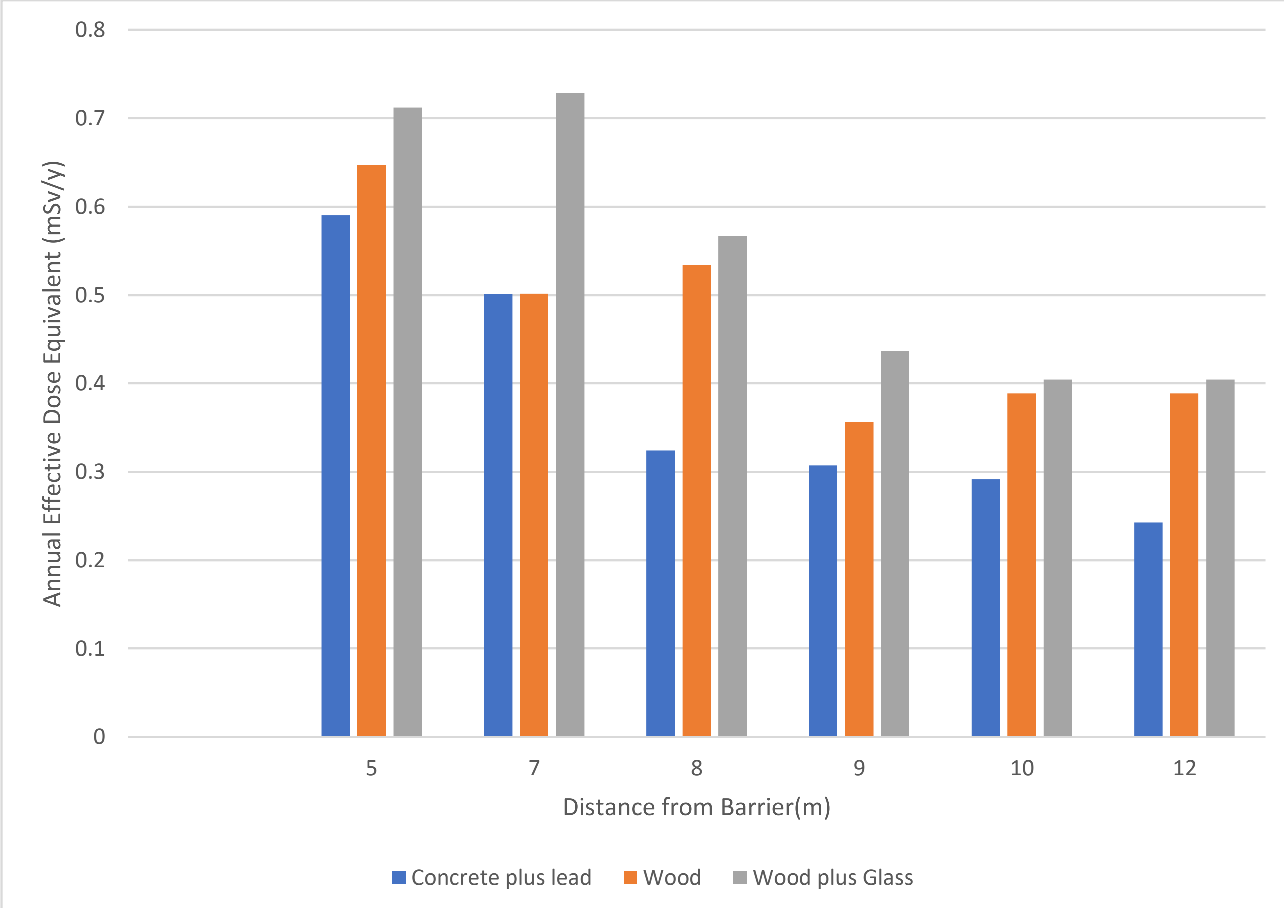

Figure 1: Comparison of effectiveness of various radiation shielding barriers with the Annual Effective Dose Equivalent at varying distances.

Discussion

According to the International Protocol, the radiation spread caused by a patient or phantom is typically less than 0.1% of the incident radiation per 0.1 m^2 of exposed area. IAEA Safety Report Series Number 47 states as much. During the study, radiological exams on patients were performed in the study area. The inverse square law is supported by measurements and calculations that indicate that dosage rates decline as one gets further away from the radiation source.

The results of the radiation dose rate measurements were shown for the concrete plus lead shielding barrier, the wood shielding barrier, and the wood plus glass shielding barrier, with values ranging from 0.05±0.01 to 0.12±0.01 µSv/hr, 0.08±0.01 to 0.13±0.01 µSv/hr and 0.08±0.01 to 0.15±0.01 µSv/hr respectively. The results show that the least measured radiation dose rates for all shielding barriers were achieved at a distance of 12 meters from the source, while all maximum measured radiation dose rates were obtained at a distance of 5 meters from the source. Variations in the measured values may be explained by variations in each shielding barrier's density, thickness, and location. It can also be as a result of changes in the construction and effectiveness of the materials as shields. As a result, the concrete and lead barrier perform better at shielding against wood, whereas the glass and wood shielding barrier exhibit the lowest recorded radiation dose rate at the closest range. For concrete plus lead, wood, and wood plus glass shielding barriers, the AEDE values ranged from 0.2428 to 0.5900 mSv/yr, 0.3884 to 0.6472 mSv/yr and 0.4044 to 0.7283 mSv/yr respectively. However, the annual effective dosage equivalent values were all below the advised limit of 1 mSv/y.

The results of this investigation are in line with those of an earlier investigation at the Cancer Institute of Guyana on an immediate dosage [11]. The results of the investigation show that radiation shielding barriers are very efficient in these situations.

For the current barriers, the ionization chamber observed far lower instantaneous dose rates than those anticipated. These findings differ from research conducted at the radiology departments of seven randomly chosen hospitals in the Duhok governorate [12].

Proved that, when compared to non-lead-containing radiation shielding materials, a number of non-lead compounds are capable of offering appropriate radiation protection. It was further demonstrated that the selection of a radiation shielding material depends on the type of radiation for which it is intended and that new polymeric materials with radiation shielding properties must be developed in order to reduce electromagnetic radiation [13].

4. Conclusion

The radiation shielding barriers present in the conventional X-ray unit of the radiology department of FTH Gombe are all appropriate and up to the standard, according to measurements, calculations, and results from this evaluation of the minimum radiation shielding barriers for X-ray facilities, which was carried out in Gombe, Nigeria. The concrete plus lead barrier was found to be the most effective. Based on the results obtained, the AEDE were within the recommended permissible limit of 1 mSv/y.

This study encourages continuous periodic radiation monitoring despite the fact that all shielding barriers in the study region are in great condition. This is done so that any damage to the barriers can be detected as soon as feasible.

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