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EFFECTIVENESS OF THE SHIELDING MECHANISM IN ROOMS HOUSING X-RAY DIAGNOSTIC EQUIPMENTS (A CASE STUDY OF MULAGO HOSPITAL, UGANDA)

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Abstract -- The effectiveness of the shielding against ionizing radiation in controlled and supervised areas of four (4) selected imaging rooms of Mulago hospital was determined. Scattered radiation transmitted to the operator's console, leakage through the walls and doors to the patient waiting areas was also determined. The effective doses to occupational workers were also determined. The availability and effectiveness of the lead aprons and other protective gears was also investigated. Thermoluminiscent Dosimeters (TLDs) were installed at selected points for a period of four (4) weeks. Radiation leakages to the members of the public were measured using a survey meter, scattered X-ray radiation to staff was measured using TLD badges. The mean scattered radiation in the imaging rooms varied from 1.19 mSv/month in the Computed Tomography (CT) room to 0.38 mSv/month from the Casualty Center (CC). The effective doses to occupational staff were highest in Room 4 (R4) (plain radiography) of 6.8 mSv/yr and lowest in CC at 1.4 mSv/yr. Radiation leakages through selected doors were found to be 18.1 mSv/hr at the Uganda Cancer Institute (UCI). Though there was some leakage, the available shielding was found to be generally effective.

Keywords — Imaging room; ionising radiation; Thermoluminiscent Dosimeter (TLD); controlled area; equivalent dose;

I. INTRODUCTION

The application of ionising radiation in medicine has greatly improved human health through diagnosis and treatment of diseases. Ionising radiation also has wide applications in industries, agriculture, environmental monitoring and water resources management and therefore forming an important tool for mankind [1]. Radiation used in medicine is the largest source of man-made radiation to which people in Uganda are exposed to, the majority of it coming from diagnostic X-rays. The use of ionising radiation in medicine although advantageous for diagnostic and therapeutic purposes and has been justified, accidental exposures of patients, radiation workers and members of the public may lead to both deterministic and stochastic effects even at low doses [2]. Medical exposures to radiation are intended to provide a direct benefit to the exposed individuals [3] and yet it is possible that some members of the public and the radiation workers are exposed to higher than the recommended doses due to the ineffectiveness of the available shielding.

In Uganda, limited study has been undertaken to investigate the shielding of imaging rooms and the status of the protective gears. This is especially in controlled and supervised areas [4], [5]. This study therefore assesses the effectiveness of the available shielding and also reports the effective doses of occupational staff in Mulago Hospital.

II. MATERIALS AND METHODS

Four imaging units in Mulago Hospital namely; UCI, R4 and CT room at the Second Floor and CC were chosen. Measurements of radiation exposure were done on plain X-ray machines at UCI, R4, CC and the CT Room which houses a 16-slice multi CT scanner in the controlled and supervised areas at measured distances from the source. The measurements were taken at patient waiting areas, areas surrounding the bunkers, operator's consoles and inside the imaging rooms. The X-ray unit at UCI is of dimensions 5.03 m × 4.2 m, R4 was 4.72 m × 5.83 m, 5.52 m × 2.82 m for the CC whereas CT was 5.76m×4.72m. Most of the rooms were congested with old and non-functional metallic equipment which rendered the rooms vulnerable to multiple scatter.

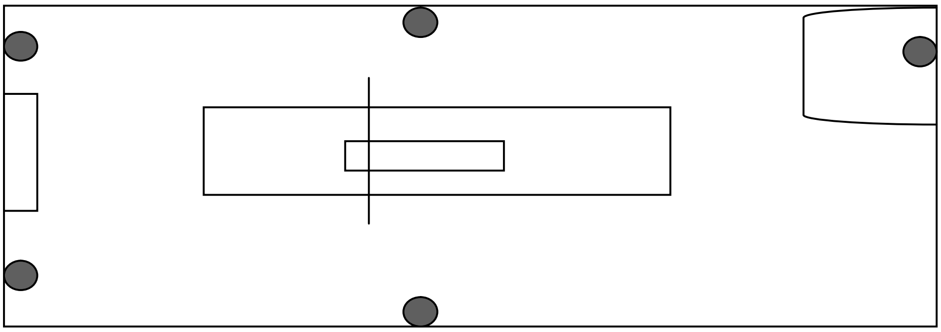

Figure. 1. Schematic diagram showing an imaging room and the position of the TLD badges for measurement of scattered radiation (horizontal view)

LiF Thermoluminiscent Dosimeters (TLDs) were given to two (2) radiation workers in each of the four selected imaging rooms to wear around their chest or waist areas when at work in the imaging unit for a period of one month and the mean values determined for each area or staff monitored. The TLD badges were collected and read out using the Harshaw TLD 4500 Reader. It consists of a TLD analyzer with a slot for inserting the TLD card and connected to a monitor. The monitor displays the glow curve of each TLD card which is an indication of the magnitude of the dose. The radiation dose trapped by each TLD can be read directly from the monitor. The Harshaw TLD reader system was calibrated using the Sr-90 Irradiator. The two radiation staffs chosen in the imaging unit were given codes e.g. X and Y in each imaging unit. The TLDs were then annealed after the data acquisition procedure and then re-used [6].

Table I: Dose limits for occupational workers and members of the public [5]

Dose limit		
	Occupation staff	Public
Effective dose	20 mSv/year averaged over a period of 5 consecutive calendar years	1 mSv in a year
Annual equivalent dose		
Lens of the eye	150 mSv	15 mSv
The skin	500 mSv	50 mSv
The hands and feet	500 mSv	-

Radiation leakages through the doors to the patients' waiting areas was monitored using a Survey meter for safety of the TLDs outside the selected imaging rooms. This Survey meter is a Mini monitor "mini-con" series 1000, serial number 003034.

It has a GM tube detector with a circular cross-section of radius 3 cm and a sensitive volume of about 115 cm^3. It was calibrated in a Secondary Standard Dosimetry Laboratory (SSDL) in Tanzania. Similar maximum exposure factors (current, time) commonly used for each imaging modality were used. A graph of the equivalent dose was plotted against the corresponding distance from the door. Leakage to the offices within the selected units was monitored using the TLD badges that were placed on the office walls. Scattered X-ray radiation in the controlled areas was monitored using TLDs. They were sealed in polythene and plastic packets and stuck in the rooms at different levels. The areas to be monitored were marked and their corresponding distances from the couch (reference point) measured using a tape measure. The distances were recorded as *x and y* for the horizontal and vertical respectively from the center of the patients couch. The crystals were then exposed for a period of one month and then taken for a data acquisition procedure. Visual and physical inspection of the status of each lead apron in each imaging unit was carried out and the suspected defective lead aprons were exposed to reveal the defects.

III. RESULTS AND DISCUSSION

Scattered radiation in controlled areas

Table II: Results of scattered radiation within the X-ray rooms at the UCI

Position	Description	x (m)	y (m)	Equivalent dose (mSv/month)
1	Besides the door	3.5	0.9	0.57
2	Control Room	1.6 m from door on the RHS	0.9	0.34
3	Besides the chest stand	2.2	0.8	0.54
4	Inside the office	3.0	0.9	0.32
5	Inside the office	1.4 m from the door	1.7 m above the ground	0.19
6	Patient admission window	N.A	N.A	0.22

Table II shows the results of the mean scattered radiation from UCI. From the results, the mean scattered radiation in the imaging room (Positions 1&3) was 0.56 mSv/month. This is a high value in a room of dimensions 5.03 m × 4.2 m when compared with the recommended value of 0.4 mSv/month for a medium sized room of 4 m × 4 m [5]. The mean leakage radiation to the control room and the adjacent office (positions 2, 4, 5 and 6) was 0.27 mSv/month respectively. This lies within the recommended dose limits.

Table III: Results of scattered radiation within R4

Position	Description	x (m)	y (m)	Equivalent dose (mSv/month)
1	Inside the Control room	2.87	1.00	0.63
2	Beside the door	3.42	0.70	0.60
3	Besides window on the right	1.15	0.96	0.52
4	Inside the Changing room	2.90	1.35	1.52

From R4, the mean scattered radiation within the controlled area (positions 2, 3 & 4) was 0.88 mSv/month. This is high within the imaging room of dimensions 4.72 m × 5.83 m when compared with the set limits [5]. This is attributed to the congested space and differences in exposure factors by radiation workers that cause a lot of scattered radiation. This presents a risk to all radiation workers with poor safety habits inside the imaging room. The mean scattered radiation transmitted into the control Room was 0.63 mSv/month. This value is low and within the recommended limits [7].

Table IV: Results of scattered radiation in CC

Position	Description	x (m)	y (m)	Equivalent dose (mSv/month)
1	Besides the chest stand	1.47	0.75	0.73
2	Opposite couch	1.52	1.30	0.40
3	Besides couch	0.67	0.00	0.43
4	Inside control room	2.60	0.60	0.23
5	Inside control room	2.60	1.24	0.38
6	Waiting corridor	3.60	0.60	0.08
7	Waiting corridor	2.57	0.70	0.28
8	Inside the dark room	2.98	1.00	0.32

From **Table IV** above**,** the mean scattered radiation within the imaging room (positions 1, 2, 3, 6 and 7) as 0.38 mSv/month. This is a room of dimensions 5.52 m × 2.82 m. Therefore the quantity of scattered radiation is higher than the acceptable limit [5]. The size of the room coupled with a large number of number of examinations carried out in a month (in excess of 2000) could account for this high value of scattered radiation. In the waiting corridor inside the imaging room (positions 6&7), the mean scattered radiation was 0.18 mSv per month. The annual derived values for these locations are 3.41 mSv and 3.79 mSv respectively which are acceptable when compared with the annual limit for a single year (50 mSv) although occupationally exposed workers and the public should not be in these areas occasionally to avoid unjustified exposures. The mean radiation transmitted through the secondary barriers (Positions 4, 5 and 8) per month was 0.31 mSv. This is low and within the recommended dose limits [6].

Table V: Results of scattered radiation in CT Room at Second floor

Position	Description	x (m)	y (m)	Equivalent dose (mSv/month)
1	Besides patients couch	2.5	1.00	0.92
2	Besides lead glass	2.40	1.45	1.46
3	Inside control room	3.08	1.10	0.56

From the results above, the mean scattered radiation within the imaging room (points 1 &2) was 1.19 mSv/month. This is higher than the recommended maximum limits [5]. Regarding size, the CT imaging room is big enough (5.76m×4.72m) to control the scattered radiation. The room however is congested with faulty and some non-functional equipments which cause multiple scatter. Also the CT machine operates in the energy range of 65 – 140 kVp that permits scattered radiation due to Compton scatter. Therefore the CT room should be decongested. In the control room, an average of 0.56 mSv/month was recorded. This is low and within the set limits [7]. Therefore the available lead shielding is safe for the radiation workers.

Table VI: Calculated annual Equivalent Doses for Staff in different imaging rooms

Room	**Radiation Worker Code**	**Estimated effective dose (mSv/yr)**
UCI	X	6.6
	Y	2.8
R4	P	5.2
	Q	6.8
CC	R	1.4
	Z	3.7
CT Room	M	6.1
	N	4.4

From the table above, the effective doses to staff are smaller than the recommended value of 20 mSv/yr for occupationally exposed staff **(Table I)** [5]. Looking the CT as an example, in the operator's room, the estimated average equivalent dose is 4.6 mSv/yr. This value is higher than the effective dose for staff N (Table VI). The actual equivalent dose accumulated by staff depends on how they operate within the dose rate distribution spectrum in the X-ray room to make their doses As Low as Reasonably Achievable (ALARA) hence Staff M and Staff N occupied different positions.

Radiation leakage through the door from selected imaging rooms

Radiation leakage through the door of UCI at different distances from the door at the same maximum exposure factors. The maximum exposure was 105 KV, 3 mAs.

Table VII: Variation of scattered and leakage with distance from the door at UCI

Distance from the door (m)	Equivalent dose (mSv)
0.0	18.1
0.3	10.3
0.6	4.05
0.9	1.80
1.2	1.01

The figures below show the variation of attenuated radiation with distance from the doors. The graphs indicates that closer to the doors, the Equivalent doses registered are very high. For similar exposure factors, the quantity of radiation is inversely proportional to the square of the distance from the reference point (door), that is, it follows the inverse square law. For exposures near the door, the intensity of the radiation beam is high but decreases with distance as the inverse of the square of the distance from the source. The dose rate value of 18.1 mSv/month implies that the door needs some lead lining to reduce the equivalent dose rate to an acceptable value.

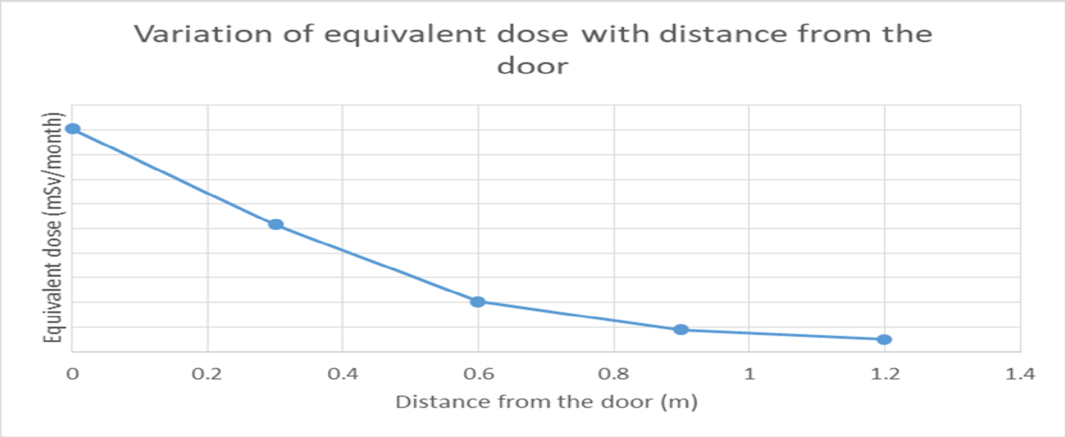

Figure 1. Variation of Equivalent dose with distance from the entrance at the UCI, Mulago

Availability and state of the shielding gadgets

Table VIII: Shielding Gadgets and corresponding number of Radiographers available in X-ray rooms at UCI, R4, CC and CT room

Imaging Center (X-ray room)	Lead aprons	Gonad shields (Lead skirts)	Lead Gloves	Radiographers present
UCI	3	0	0	5
Department of Radiology				
R4	2	1	0	5
CT room	2	0	0	5
CC	2	1	0	5

From **Table VIII** above, the number of protective gadgets physically present in the imaging rooms was not proportional to the actual number of staff available in the room since other lead aprons and lead skirts are kept in the store.

It was noted that the main shielding mechanism used by the majority of staff is the operator's console (lead glass). The lead aprons are left to the comforters. Suspicious lead aprons from the study centers were carefully analyzed using the image viewer. However there were no cracks or faults leading to leakages were found from the exposures taken on them as shown in **Figure 2**. From **Table VIII** above, the number of protective gadgets physically present in the imaging rooms was not proportional to the actual number of staff available in the room since other lead aprons and lead skirts are kept in the store. It was noted that the main shielding mechanism used by the majority of staff is the operator's console (lead glass). The lead aprons are left to the comforters. Suspicious lead aprons from the study centers were carefully analyzed using the image viewer. However there were no cracks or faults leading to leakages were found from the exposures taken on them as shown in **Figure 2**.

Figure 2: X-ray film of an apron from the CC showing no defects

IV. CONCLUSION

There is a high scattered radiation in all the controlled areas. The occupation 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 congestion leading to multiple scatter. Due some leakage at the doors, it is advisable to put a warning notice or warning lights to discourage anyone to stand directly opposite the entrance when the X-ray is in operation. Also of concern is the changing room in R4 (position 4). There is some scattered radiation measured but since it has no full occupancy, the risk is low [8]. Generally, the available shielding was effective.

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