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Analysis of the Current Radiation Shielding Walls and Doors in Selected Hospitals in Uganda

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***Abstract**: Various types of concretes as primary shielding materials are in use for medical radiation facilities such as diagnostic radiology, nuclear medicine and radiotherapy rooms. The cost and use difficulties as well as being opaque to visible light that is quite impossible to look through a concrete-based radiation shield can also be said to be another disadvantage. In theory, it can be said that any material with a certain material density and thickness can reduce the radiation. Therefore, different types of alternative materials namely building materials, bricks, polymers, steel, resins, composites and alloys have been investigated by different researchers for their possible radiation shielding applications. In this paper, we compare the conventional radiation shielding walls and doors used in selected hospitals in Uganda and the improved version. The result shows that the improved radiation shielding walls and doors has greater benefits such as: Reduces use of limited resources, reduces costs, reduces radiation levels, converses the environment, increase performance (productivity, durability) and saves time.*

Keywords— Radiation, Shielding, Materials, diagnostic, doses

1. INTRODUCTION

The need to obtain a clinical image of sufficient quality to provide the relevant diagnostic information is of paramount importance. Justification is achieved by providing clinical practitioners with information about the potential health detriment from each medical exposure based on an assessment of dose and risk that can be weighed against the medical benefit. Optimization is accomplished by ensuring that those who carry out the exposure know how the techniques and equipment factors that they select affect the quality of the clinical image and the dose received by the patient [1]. Periodic assessments of patient doses are undertaken to ensure that the levels are appropriate, taking account of possible implication for image quality. Also, there has been tremendous increase radiation leakages in diagnostic radiology arising from high costs of improvement of the existing medical facilities. Also during the construction of Radiation room they still use the old methods which are expensive and time consuming meaning with small funds such construction designs are hard to complete in time hence leading to a delay in radiation medication exercise which can lead to delay and poor radiation doze given hence death of patients in the long run. These calls for the need for appropriate radiation shielding wall [2]. Traditionally, various types of concretes as primary shielding materials are in use for medical radiation facilities such as diagnostic radiology, nuclear medicine and radiotherapy rooms [3][4]The cost and use difficulties as well as being opaque to visible light that is quite impossible to look through a concrete-based radiation shield can also be said to be another disadvantage. In theory, it can be said that any material with a certain material density and thickness can reduce the radiation. Therefore, different types of alternative materials namely building materials, bricks, polymers, steel, resins, composites and alloys have been investigated by different researchers for their possible radiation shielding applications. Another alternative radiation shielding material is known as glasses [4]. Due to their several significant advantages such as cheap cost, optical transparency for visible light, ease of production in different sizes and forms with no variation in their composition and density with external fields makes glasses attractive and in recent years, are of interested to investigate them by many researchers as encouraging materials for ionizing radiations such as X-ray, gamma and neutron radiation shielding [5].

The range of materials which may be used to provide radiation shielding include:

- Lead sheet and lead fabricated products (lead plywood, lead plasterboard).
- Concrete, concrete blocks and concrete products.
- Barium plaster.
- Various types of brick.

- Gypsum wallboard.
- Lead glass.
- Lead acrylic.
- Other materials (e.g. steel and wood for low energy/mammography trailers).

The choice of material depends on several factors, including the level of shielding to be achieved, the cost, and the practicalities of installation [2][6].

1.1 GUIDANCE ON COMMISSIONING OF NEW RADIOLOGY EQUIPMENT IN UGANDA

1. Internally, agree on the purchase specifications of the equipment as per the current and future needs of the facility.
2. Notify Council of the intention to acquire and install the new equipment.
3. Agree with the supplier of the equipment on the acceptance tests that will be performed and the expected results.
4. Upon installation, ensure that the supplier carries out acceptance tests in your presence
5. Compare the results in 4 with those in 3 above to help you decide whether to accept or reject equipment.
6. Carry out commissioning tests using a competent person as per the quality control program specific to the type of the equipment. Please note that all clinically used physical parameters for either image quality of diagnosis must be determined to acquire baseline data. Commissioning results must comply with the regulatory limits of Atomic Energy Council.
7. Carry out a safety assessment of the premise by performing radiation survey measurements in the control cubicle, through the viewing glass, doors, windows, walls, corridors, adjacent rooms etc. Please calculate the estimated doses for where occupancy is envisaged in the supervised and controlled areas.
8. Take corrective actions if the performance parameters do not meet the performance criteria.
9. Submit the results in 4, 6 and 7 above to Atomic Energy Council and request for a verification inspection.
10. Comply with authorization requirements.
11. Upon being authorized, commence the operations.

2. METHODOLOGY

Beam alignment was done using Collimation test tool, loaded cassette and Beam alignment test tool with FFD of 1m, 66kV and 7.1mAs as the testing parameter.

Kv Accuracy was maintained using IBA Dosimetry GmbH (Model: VD022030, S/N: R13-0223 2163, Version 1) adjusted to FFD of 1m and fixed mAs of 20 as the parameter setting.

2.1 RADIATION SHIELDING DOOR IMPROVEMENT

Materials include barium meal (barium sulphate), varnish and posh or wood paste.

TABLE 1: CURRENT LEAD CODES FOR THICKNESS AND WEIGHT

	Code3	Code4	Code5	Code6	Code7	Code8
Nominal thickness (mm)	1.32	1.80	2.24	2.68	3.15	3.55
Weight (kg/m2)	15.0	20.5	25.5	30.1	35.8	40.4
Weight of 3000 x 300mm sheet (kg)	13	18	23	27	32	36
Weight of 6000 x 300mm sheet (kg)	27	37	46	54	64	72

2.2 FACILITY DESIGN AND LAYOUT

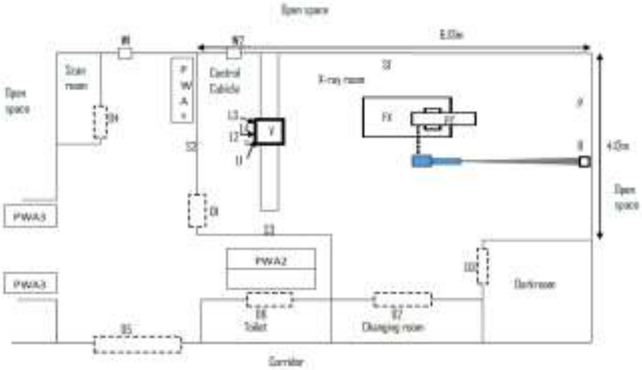


Figure 1: Facility design and layout proposed

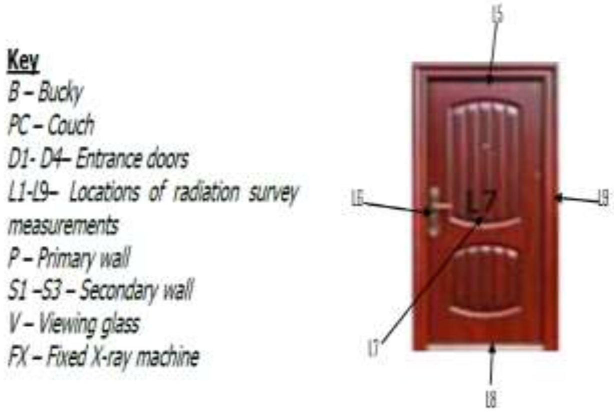
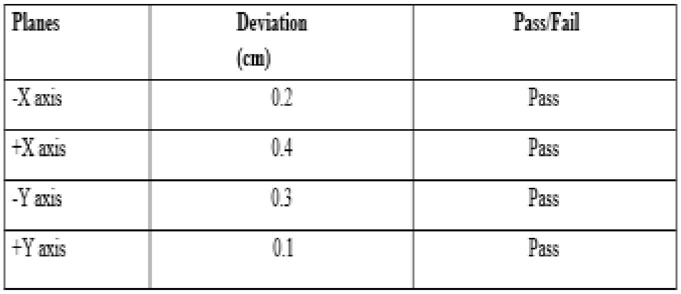


Figure 2: Door, D1 Assessment

3 Results

3.1 BEAM ALIGNMENT

TABLE 2: DEVIATION OF X-RAY AND LIGHT BEAMS ALONG THE X AND Y PLANES



Planes	Deviation (cm)	Pass/Fail
-X axis	0.2	Pass
+X axis	0.4	Pass
-Y axis	0.3	Pass
+Y axis	0.1	Pass

From table 2, the deviation between the X-ray & light fields along the X and Y axes were within the recommended limit of 1cm.

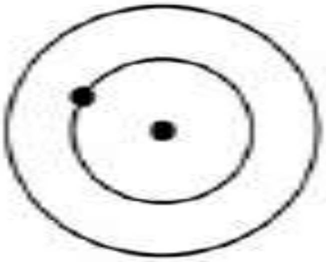
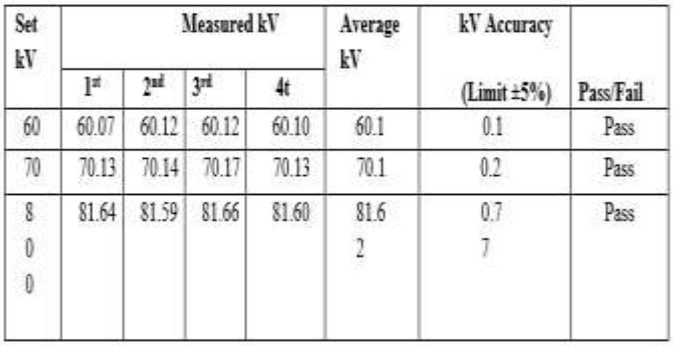


Figure 3: X-ray and light beam perpendicular alignment

From figure 3, the image of the top ball intercepted the first circle. Therefore, the beam was aligned by 1.50 away from the perpendicular central ray.

3.2 KV ACCURACY

TABLE 3: KV ACCURACY FOR THE FIXED X-RAY MACHINE

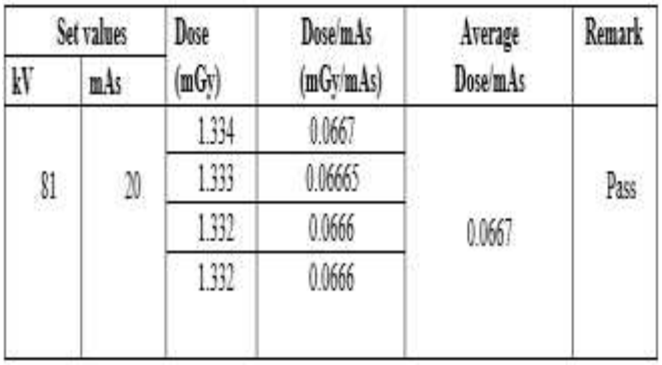


Set kV	Measured kV				Average kV	kV Accuracy (Limit ±5%)	Pass/Fail
	1st	2nd	3rd	4t			
60	60.07	60.12	60.12	60.10	60.1	0.1	Pass
70	70.13	70.14	70.17	70.13	70.1	0.2	Pass
800	81.64	81.59	81.66	81.60	81.62	0.77	Pass

From table 3, the percentage errors in the measured kV values at 60, 70 and 81kV were within the recommended error range of ±5%. Thus the fixed X-ray machine delivered accurate kV at these settings.

3.3 NORMALIZED OUTPUT AT 81KV, FFD 1M

TABLE 4: NORMALIZED OUTPUT FOR THE FIXED X-RAY MACHINE



Set values		Dose (mGy)	Dose/mAs (mGy/mAs)	Average Dose/mAs	Remark
kV	mAs				
81	20	1.334	0.0667	0.0667	Pass
		1.333	0.06665		
		1.332	0.0666		
		1.332	0.0666		

From table 4, the average normalized output was within the recommended range of 0.025 mGy/mAs -0.080 mGy/mAs at 81 kV and FFD 1m.

3.4 RADIATION SURVEY MEASUREMENTS

Analysis of the shielding wall

The existing wall (shielding wall) has a thickness of 230 mm of CB-2 with 182 square metres corresponds to the cost of 2152 Ugx shs which is average, the 230 mm of CB-2 in turn corresponds to code 7 of lead per square meter which gives 3.15 mm thickness of lead.

Note that code 7 gives 32 or 64kg of lead depending on the dimensions of lead.

If we take 64kg

Lead cost per kg = 80,000Ugx shs

64kg of lead = 64 x 80,000 =

This yielded an average shielding value of 9.2µsv/h

But on using interlocking soil stabilized barium brick the thickness was 140 mm its average cost was 7875 Ugx shs. This requires lead equivalence of 1 to 1.32 mm of lead which corresponds to code 3 which gives 13 to 27kg depending on the type of lead sheet.

Lead cost per kg = 80,000Ugx shs

27kg of lead = 27 x 80,000

This yielded an average shielding value of 9µsv/h as recommended.

So the cost benefit analysis of shielding wall existing and the new one made of barium bricks shown as below;

Costs incurred for existing wall = 21525 Ugx shs

Costs incurred for ISSBB-U = 7875

= 21525 – 7875

= 13,650 Ugx shs

It should be noted that using ISSBB-U in shielding wall construction saves 13650 Ugx shs as compared to CB-2.

Lead Equivalence calculations

When using ISSBB-U of 140mm, the lead cost and equivalence of 1 to 1.32mm thickness is

27 x 80,000 = 2,160,000 Ugx shs

When using CB-2 of 230 mm, the lead cost and equivalence of 3.15 mm thickness is

64 x 80,000 = 5,120,000 Ugx shs

Lead cost saved when using ISSBB-U = 5,120,000 – 2,160,000 = 2,960,000 Ugx shs

Lead thickness saved when using ISSBB-U =3.15– 1.32 mm

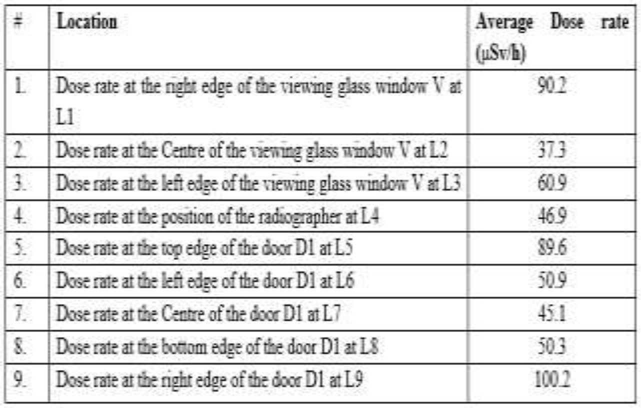
= 1.82 mm thickness of lead is saved.

Standard lead thickness, weights and weights per square metre for lead sheet updated as shown below using BIR codes of 2012. This was so useful in the ISSBB-U, CB-2 and lead equivalence analysis.

3.5 ANALYSIS RADIATION SHIELDING DOOR IMPROVEMENT

Radiation survey measurements before improvement of radiation dose rate yielded the following results

TABLE 6: RESULTS BEFORE IMPROVEMENT



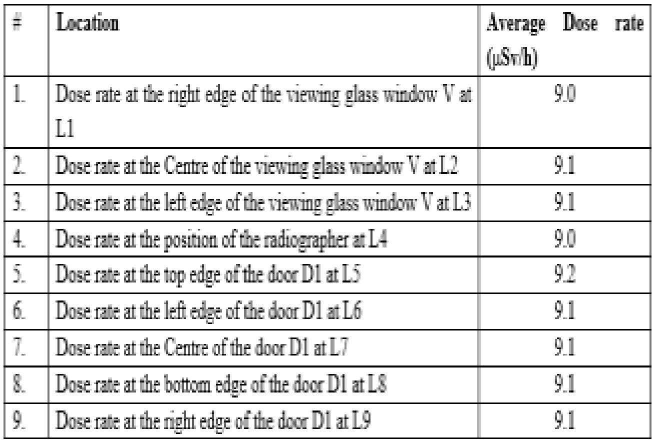
#	Location	Average Dose rate (μSv/h)
1.	Dose rate at the right edge of the viewing glass window V at L1	90.2
2.	Dose rate at the Centre of the viewing glass window V at L2	37.3
3.	Dose rate at the left edge of the viewing glass window V at L3	60.9
4.	Dose rate at the position of the radiographer at L4	46.9
5.	Dose rate at the top edge of the door D1 at L5	89.6
6.	Dose rate at the left edge of the door D1 at L6	50.9
7.	Dose rate at the Centre of the door D1 at L7	45.1
8.	Dose rate at the bottom edge of the door D1 at L8	50.3
9.	Dose rate at the right edge of the door D1 at L9	100.2

The results obtained in the table from all the locations where above the maximum recommended radiation dose of 10μSv/h hence making the working environment for radiation workers and members of the public unsafe.

But on shading of these locations with a mixture of barium meal (barium sulphate), varnish and posh or wood paste the shielding properties of the doors and windows improved.

Mixing ratio ($^1/_2$: ½: ½: ½) that $BASO_4$: Varnish: posho: wood paste hence that table radiation dose reduced to the required recommended.

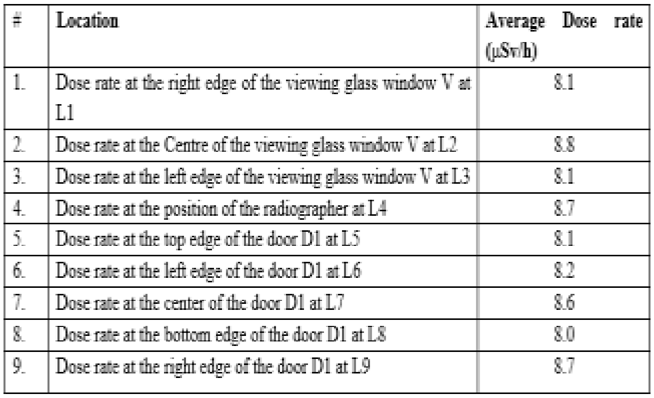
TABLE 7: RESULTS AFTER THE FIRST IMPROVEMENT (ON ADDITION OF 0.3MM THICKNESS)



#	Location	Average Dose rate (μSv/h)
1.	Dose rate at the right edge of the viewing glass window V at L1	9.0
2.	Dose rate at the Centre of the viewing glass window V at L2	9.1
3.	Dose rate at the left edge of the viewing glass window V at L3	9.1
4.	Dose rate at the position of the radiographer at L4	9.0
5.	Dose rate at the top edge of the door D1 at L5	9.2
6.	Dose rate at the left edge of the door D1 at L6	9.1
7.	Dose rate at the Centre of the door D1 at L7	9.1
8.	Dose rate at the bottom edge of the door D1 at L8	9.1
9.	Dose rate at the right edge of the door D1 at L9	9.1

The above table yielded an additional thickness 0.3mm on further increasing the shading to 0.6mm thickness the table yielded.

TABLE 8: FURTHER IMPROVEMENT RESULTS (ON ADDITION TO MAKE 0.6MM THICKNESS)



#	Location	Average Dose rate (μSv/h)
1.	Dose rate at the right edge of the viewing glass window V at L1	8.1
2.	Dose rate at the Centre of the viewing glass window V at L2	8.8
3.	Dose rate at the left edge of the viewing glass window V at L3	8.1
4.	Dose rate at the position of the radiographer at L4	8.7
5.	Dose rate at the top edge of the door D1 at L5	8.1
6.	Dose rate at the left edge of the door D1 at L6	8.2
7.	Dose rate at the center of the door D1 at L7	8.6
8.	Dose rate at the bottom edge of the door D1 at L8	8.0
9.	Dose rate at the right edge of the door D1 at L9	8.7

Hence increasing the thickness reduces the radiation dose rate. All the above was obtained by using water phantom, survey meter (model: XCplus). Set to parameters 96kV and 20mAs on background radiation of 0.103μSv/h.

Note that 10μSv/h is the maximum radiation dose rate recommended by Atomic Energy Regulation Act of 2012 Uganda.

4. Conclusion

The analysis of the shielding from radiation in a medical facilities or hospital, compares the shielding of the conventional radiation shielding facilities and the improved radiation shielding facilities that makes use of locally. The result shows that the improved radiation shielding walls and doors has greater benefits such as: Reduces use of limited resources, reduces costs, reduces radiation levels, converses the environment, increase performance (productivity, durability) and saves time.

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