NUCLEAR SCIENCE

PRACTICAL EVALUATION OF THE BIOLOGICAL SHIELDING EFFECTIVENESS OF THE GAMMA IRRADIATION FACILITY AT KWABENYA, GHANA

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ABSTRACT

The ability of re-inforced concrete to attenuate photons in a facility housing a 50 kCi Cobalt-60 source has been practically assessed using a Chinese made dose rate survey meter model SG-102. Within the maze entrances, the measured dose rates were 6273.8 ± 745.7nGy/hr (Personnel) and 755.4 ± 94.4 nGy/hr (Goods). Outside the maze entrances and behind the lead shielding doors, the dose rates were 288.9 ± 81.3 nGy/hr (Personnel) and 199.5 ± 60.7 nGy/hr (Goods). At other locations within the facility, the dose rates determined were as follows: 303.4 ± 23.2 nGy/hr (concrete roof top), 3984.0 ± 78.7 nGy/hr over the small water pool in the de-ioniser room, whereas values obtained for the control, electrical and the de-ioniser rooms were not significantly above background readings. These measured values are consistent with theoretical estimates.

Keywords: *Dose, dose rate, gamma radiation, attenuation.*

INTRODUCTION

A 50 kCi Cobalt-60 multipurpose Gamma Irradiation facility was commissioned in March 1995 at the Radiation Technology Centre (RTC) of the Ghana Atomic Energy Commission (GAEC), Kwabenya, near Accra. The installation of this facility was made possible through a technical assistance program of the International Atomic Energy Agency (IAEA). The supplier of the irradiation sources was the Institute of Isotopes of the Hungarian Academy of Sciences (INISO) Budapest, Hungary.

The shielding design for the facility was jointly undertaken by a Ghanaian architect and the Hungarian experts with an expected loading capacity of 500 kCi of Cobalt-60. The shielding design constitutes an important part of the irradiation facility as it must be able to:

1. Physically protect (shield) personnel working in and around the irradiation chamber when the sources are in storage or working positions.

2. Minimise the level of radiation received by operators and staff that may stay close to the entrances leading to the chamber and walls adjacent to the irradiation chamber.

The first of these objectives may be achieved through the use of dry concrete, maze design or wet storage (water pool). To meet the second objective, concrete and lead doors (at the maze entrances) may be used to reduce the photons to acceptable limits or As Low As Reasonably Achievable (ALARA) as recommended [2-4].

This work assesses the extent to which the biological shields at the centre are capable of protecting personnel in and around the facility. For this assessment, we used a Chinese made sodium iodide detector model SG-102 fitted with an external digital multimeter readout. Dose rate values were determined at specified locations within and around the facility. The results obtained are compared to theoretical computations earlier on undertaken by Emi-Reynolds and Akaho [1] where applicable.

DESCRIPTION OF THE FACILITY

The layout of the facility is shown in figure 1. The average thickness of the wall is 1.7m and is made of re-inforced concrete.

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The goods door, like the personnel door, has lead lining and is encased within an iron frame and opens into a maze. The personnel maze measures 1.2m wide by 1.5m high. The size of the irradiation chamber measures approximately 5m long by 4m wide by 4m high. A de-ionised water pool buried in the floor of the irradiation chamber, measures 3m long by 2 m long by 5.7m deep and is lined with re-inforced stainless steel plates. The pool serves as the biological shield for the irradiation sources while they are in the storage position at the bottom of the water column.

The irradiation unit consist of 50 kCi of Cobalt distributed equally among 20 torpedoes each of length 45.1cm in a circular diameter of 280mm. A hoist motor system located on the roof of the irradiation chamber (1.6m thick) brings the source cage from the de-ionised water pool to the irradiation position. At this position, the centre of symmetry of the radiation sources are reported to be 75cm above the floor of the irradiation chamber [5]. Two ventilation units located on the roof of the irradiation chamber have nozzles through which noxious gases produced during the irradiation process are drawn through filters out of the chamber. Two cylindrical holes at the roof of the irradiation chamber have been plugged with lead and concrete. These holes are available for future upgrading of the irradiation source to an industrial capacity of 500 kCi of Cobalt.

EXPERIMENTAL PROCEDURES

An SG-102 monitor was used for determining gamma dose rates at specified locations within and around the irradiation facility. This monitor was fitted with an external digital multimeter model DT-830 to convert the analog display signals to a digital readout enabling precise recording of the significant figures. The range of measurements is from 0-1000 μrad/hr (0-10 μGy/hr).

Before use, the SG-102 monitor was calibrated against the Secondary Standard (SS) ionisation chamber [6] at the Radiation Protection Board of Ghana.

Tablel 1: Summary of measured dose rate on Personal door

Location	Measured dose rate (nGy/hr) Source up (A)	Net dose rate nGyhr 1(A-B)
A1	472.3 ± 59.9	44.8
A2	716.2 ± 38.9	288.7
A3	507.4 ± 40.6	79.9
A4	446.2 ± 45.7	18.7
A5	445.2 ± 43.4	17.6
B1	448.4 ± 53.4	20.9
B2	454.4 ± 54.2	26.9
B3	433.3 ± 55.6	5.8
B4	429.1 ± 63.9	1.6
B5	441.2 ± 49.0	13.6
C1	440.2 ± 63.6	12.7
C2	433.4 ± 39.4	5.9
C3	422.3 ± 80.3	5.2
C4	421.2 ± 52.9	6.3
C5	444.9 ± 68.1	17.4
D1	437.9 ± 47.1	10.4
D2	432.9 ± 42.1	5.4
D3	426.8 ± 45.0	0.8
D4	424.2 ± 33.0	3.3
D5	443.7 ± 76.1	16.2
E1	439.5 ± 45.0	12.0
E2	430.0 ± 31.1	2.5
E3	427.0 ± 59.7	0.5
E4	433.4 ± 41.0	5.9
E5	432.5 ± 35.2	4.0

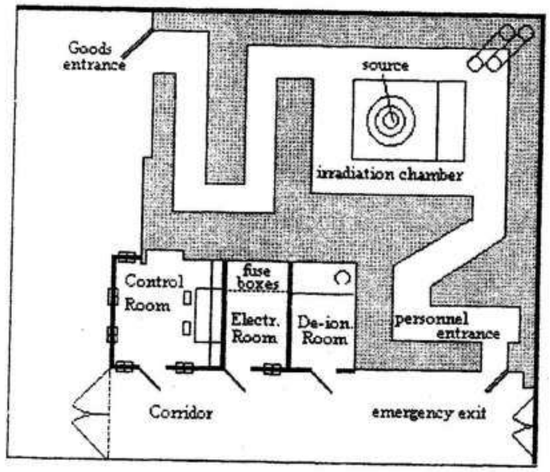
B = Average background reading 427.5 ± 71.4 nGy/hr.

To determine the net dose rate levels within and around the irradiation facility, two sets of measurements were made:-

(i) the background radiation levels at specified locations when the sources were in the safe storage position; and

(ii) dose rate levels when sources were in the unshielded position at positions previously determined in (i).

For each location shown in Figures 1, 2 and 3, at least 10 sets of readings on the SG-102 monitor were taken at 10s intervals and the average values determined.



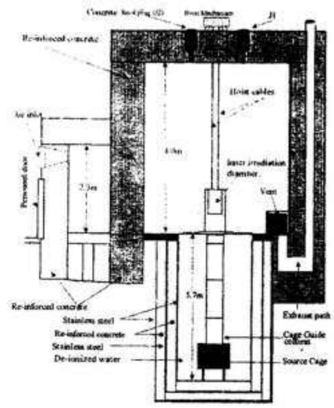


Figure 1: Plan view of the irradiation facility showing the control room and entry ports into the irradiation chamber. All dose rate readings except otherwise specified are taken at 80 cm from the floor (Figure not to scale)

Figure 2: Vertical section through part of the facility showing the irradiation chamber, water pool, hoist motor system and roof Plugs J1 and J2 (Figure not to scale)

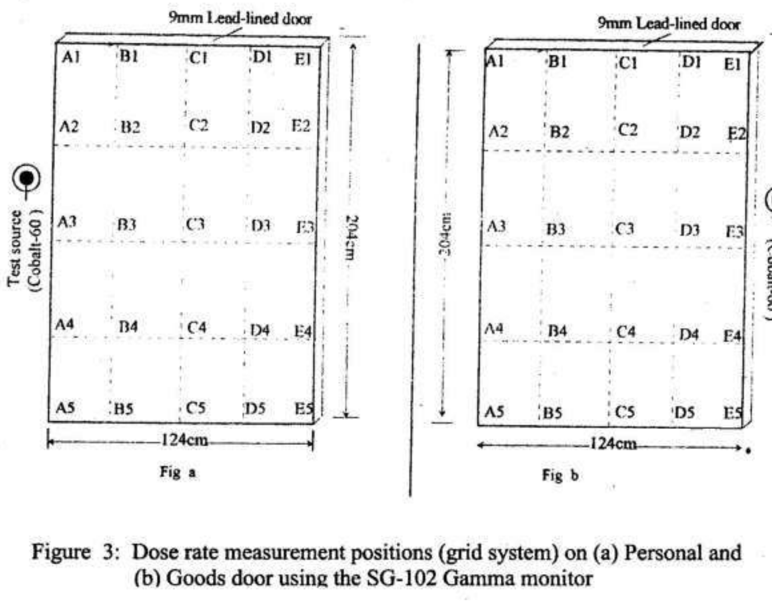


Figure 3: Dose rate measurement positions (grid system) on (a) Personal and (b) Goods door using the SG-102 Gamma monitor

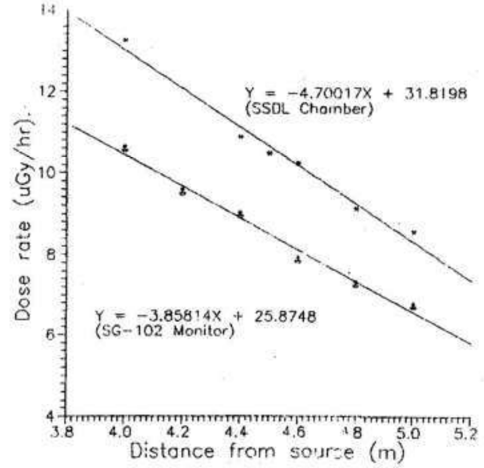


Figure 4(a): Calibration curve for SSDL environmental chamber and SG −102 survey monitor. Calibration date 17/09/96

Figure 4 (b): Dose rate values of SSDL versus SG-102 dose rate values. Calibration date 17/09/1996

RESULTS AND DISCUSSION

The calibration curves of the SS chamber and the SG-102 monitor are presented in Figures 4 (a) and (b). We observe from 4 (a) that the response of the systems are linear and that the dose rate decreases as the distance of the detector increases from the source. The relationship between the SS chamber and the SG-102 monitor is presented in 4 (b) where we note that the response of the former is related to the latter through the equation

$$Y\ (nGy/hr) = 1.21017X\ (nGy/hr) + 368.1$$

where Y and X are the dose rate readings of the SS chamber and SG-102 monitor respectively. The results presented in Tables 1 to 4 have been corrected using this equation.

In Table 1, the average background reading obtained was 427.5 $\pm$ 71.43 nGy/hr. For positions A2 and A3 however, the average background readings were much higher due to the presence of a Cobalt-60 check source imbedded in the concrete wall close to these positions. This check source is provided for checking the working condition of the portable dose rate meter each time before entry into the maze. The "background" readings for these 2 positions thus include a measure of the strength of the check source. A similar explanation holds for positions E1 and E2 of table 2 for the goods door. Apart from the deviations mentioned, the net dose rates within the facility are generally less than 44.8 nGy/hr.

Net dose rates at occupied areas within the facility when the radiation sources are up are presented in Table 3. We note that the unshielded measurements lie within the background for the control and electrical rooms. In the de-ioniser room, a net dose rate of 3984.0 $\pm$ 78.7 nGy/hr was obtained at the surface of the small water pool (position H). This value is quite high and may be explained as follows: position H is the entry point of the trench that carries the inlet and outlet pipes from the de-ioniser columns to the water pool in the irradiation chamber and back for recycling respectively. This trench is filled with mild steel shots to scatter and attenuate photons from the irradiation chamber. The value obtained suggests that there is still some radiation leakage from the irradiation chamber through the pipes and possibly areas surrounding the trench, into the de-ioniser room. Though this does not pose any radiation risk problem as the annual dose limit is not exceeded [3] personnel activity around the water pool area should nevertheless be restricted especially when the radiation sources are unshielded inside the irradiation chamber.

At the maze entrances, the net dose rates were 5846.3 ± 706.8 nGy/hr (Personnel) and 327.9 ± 41.0 nGy/hr (Goods). The value at the personnel door is quite high and confirms experimentally earlier theoretical computations undertaken [1]. These values reduce to less than 44.8 nGy/hr when the lead doors are firmly in place. The provision of these 9mm led-lined doors are thus justifiable on the basis of serving both as physical barriers when sources are up and in attenuating photons reaching them from the irradiation chamber.

At the surface of the water pool inside the irradiation chamber, the dose rate when the sources are in the storage position was 414.3 ± 25.0 nGy/hr which is within background readings observed at the facility.

Table2: Summary of measured dose rate on Goods door

Location	Measured dose rate (nGy/hr) Source up (A)	Net dose rate nGyhr (A-B)
A1	433.7 ± 55.3	10.6
A2	434.2 ± 4.0	11.1
A3	429.3 ± 8.5	6.2
A4	428.8 ± 10.3	5.7
A5	428.1 ± 15.6	5.0
B1	429.1 ± 23.0	6.0
B2	429.1 ± 15.4	6.0
B3	424.2 ± 6.41	1.1
B4	422.2 ± 13.3	0.9
B5	423.9 ± 8.3	0.8
C1	428.5 ± 67.1	5.4
C2	420.4 ± 12.7	2.7
C3	420.8 ± 14.5	2.3
C4	424.0 ± 21.5	0.9
C5	427.4 ± 9.6	4.3
D1	436.0 ± 35.8	12.9
D2	427.5 ± 24.4	4.4
D3	431.7 ± 6.6	8.6
D4	426.2 ± 12.5	3.1
D5	425.1 ± 9.0	2.6
E1	450.1 ± 13.3	27.0
E2	535.8 ± 34.4	112.7
E3	622.6 ± 31.1	199.5
E4	445.5 ± 8.4	22.4
E5	427.0 ± 14.9	3.9

@ = Background dose rates 423.1 ± 52.1 nGy/hr.

Table 3: Dose rate values within the facility

Location		Measures dose rate (nGy/hr) Source up (A)	Net dose rate nGy/hr |(A-B)|
Control Room	A	428.9 ± 16.2	5.2
	B	428.5 ± 8.6	4.7
	C	433.2 ± 13.7	9.5
	D	434.3 ± 26.3	10.5
	E	431.2 ± 3.2	7.5
Electrical Room	F	433.5 ± 16.1	9.8
	G	426.3 ± 23.1	1.2
De-ionizer Room	H	4407.7 ± 60.7	3984.0
	II	426.3 ± 23.1	2.55
Pool Surface		----------	34.7@

@ Reading obtained when source was at the bottom of the pool.
B = Background reading on meter = 423.7 ± 50.1 nGy/hr

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