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SHORT COMMUNICATION

Dosimetry of Cobalt 60 Gamma Chamber

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ABSTRACT

Ferrous sulphate-benzoic acid-xylenol orange (FBX) dosimetric system is linear in the range from 0.01 Gy to 10 Gy and can be used in the case of a nuclear accident, for documenting clinical doses in total-body irradiations in radiation therapy as well as for measuring daily radiation dose during external beam therapy because of its tissue-equivalency. FBX system is stable up to 15 days in the range 15°- 60 °C. It is independent of photon energy up to 3 keV and is fairly dose rate independent in the range from 0.01 to 2.5 Gy/min. Besides its use in radiation therapy, external beam therapy and nuclear accidents, the present study shows that this dosimeter can be effectively used for determining positional variation inside the gamma chamber. This has been detected by placing dosimetric solutions in small bottles kept in two racks of the phantom in a symmetrical fashion. Average variations in two racks were found to be 2.74 per cent, 0.33 per cent, 4 per cent and 4.83 per cent.

1. INTRODUCTION

The International Commission on Radiation Protection (ICRP) 60 gives different dose limits to different parts of the body for occupational workers and general public as 100 mSv in five years. The values range from 150 mSv to 500 mSv for occupational workers and 15 mSv to 50 mSv for the public. It is, therefore, essential to monitor the total exposure to the body so that the exposure does not exceed 1 mSv per year in India[2,3]. Medical examination is necessary when the limit crosses 15 mSv per year[4]. In this range, thermoluminiscence dosimeters (TLD) can be used. But the dose measured by these dosimeters needs to be corrected for getting tissue-equivalent dose[5].

In the case of nuclear accidents and for documenting clinical doses in total-body irradiations in radiation therapy and external beam therapy, chemical dosimeters can be used since these are tissue-equivalent. Ferrous sulphate-benzoic acid-xylenol orange (FBX) dosimeter has been used for this purpose as it is also tissue-equivalent, linear in response from 0.01 Gy to 4.0 Gy, stable for 15 days in the range 15° to 60 °C, fairly dose rate independent (0.01–2.5 Gy/min) and is independent of photon energy up to 3 keV. This dosimeter has been used for the determination of absorbed dose distribution for cobalt teletherapy source and its characteristics have been reported[6-15].

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The objective of the present study is to find the positional variation of absorbed dose inside the gamma chamber. Gamma chamber is widely used for irradiation of small animals, experimental solutions, cell cultures, etc. Absorbed dose inside the gamma chamber can be calibrated using FBX dosimeter.

2. MATERIALS & METHODS

2.1 Chemicals

The constituents of FBX dosimetric system are: ferrous ammonium sulphate (0.20 mM); xylenol orange (0.20 mM) and benzoic acid (5.0 mM) in sulphuric acid (0.05 N). All these

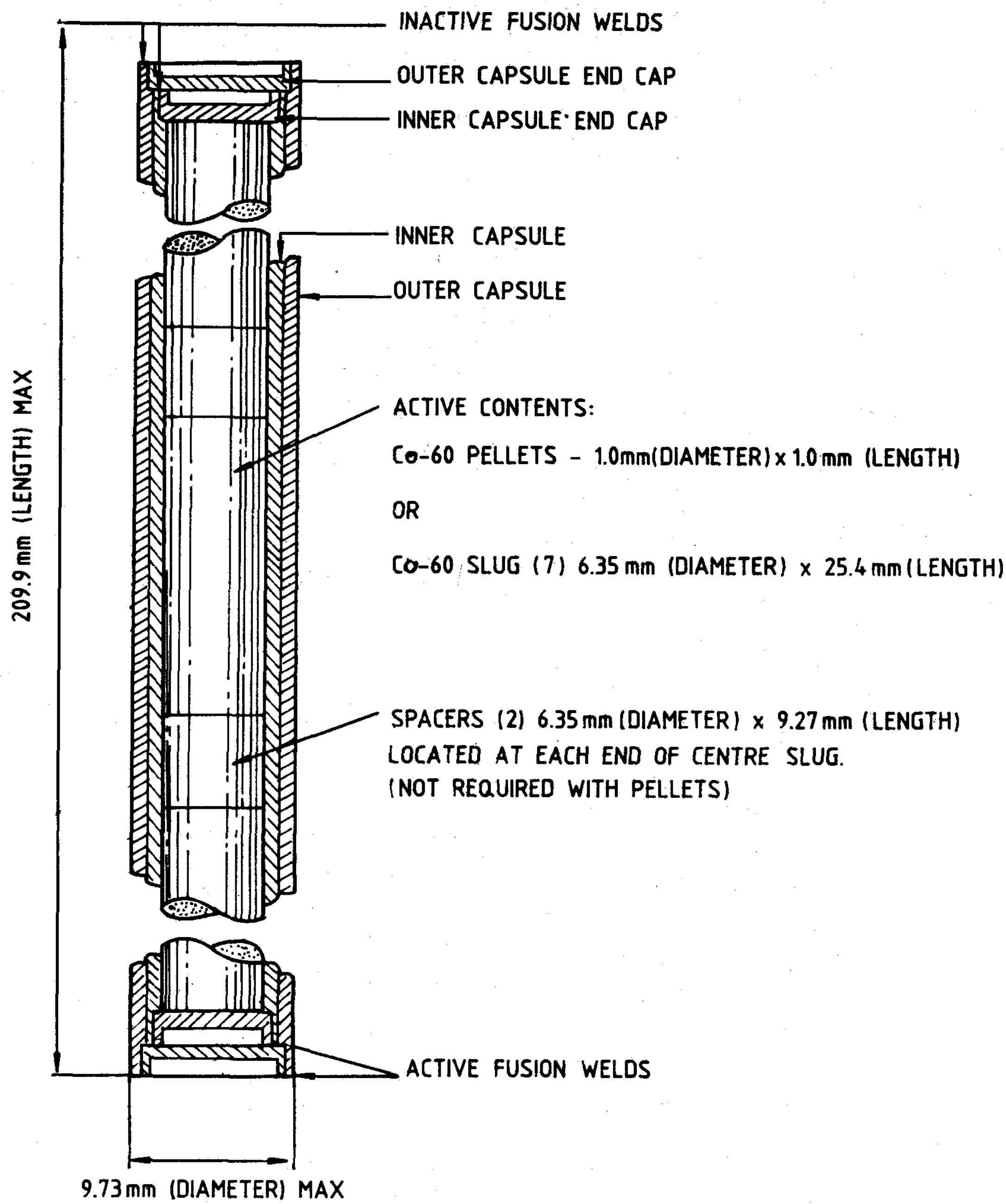

Figure 1. Geometry of the needle sources inside the gamma chamber

chemicals were obtained from E. Merck & Co (BDH). Triple distilled water was used for preparing the solutions.

2.2 Gamma Cell-220

Figure 1 shows the geometry of the needle sources placed inside the gamma chamber. The length and the diameter of active chamber are 20.97 cm and 0.973 cm, respectively. The inner capsules consist of inactive part, spacers and active part. A total of 48 cobalt 60 needle sources are situated inside the active cylindrical chamber. The diameter and the length of these pencils are 0.635 cm and 2.54 cm respectively. The gap between the two active pencils is 0.0965 cm. In each quadrant of the circular annular space, 12 active pencils are situated.

2.3 Phantom & Position of Dosimeters

The object to be irradiated was placed in the central part of the circular space. The plastic bottles were placed inside a phantom of polystyrene which could be placed inside the gamma chamber in circular racks, symmetrically, five bottles in each rack (Fig. 2).

2.4 Irradiation of Dosimeter Vials & Measurement of Doses

FBX solution (5 ml) was placed in plastic bottles (diameter: 2 cm, height : 3 cm and thickness: 1 mm). The p*H* of these solutions ranged between 1.35 to 1.40 as measured by a p*H* meter (Toshniwal, Chandigarh) of accuracy ± 0.01 p*H* unit.

These solutions were irradiated in Gamma Cell-220, Atomic Energy Canada Ltd. (AECL), Canada, at a dose rate of 0.021-0.0205 Gy/s for a total dose of 3 Gy. Calibration curve of FBX dosimeter for difference of absorbance at 540 nm $(\Delta A_{540\,nm} = A_{irr} - A_{unirr})_{540\,nm}$ was plotted against dose (Fig. 3). The absorbance measurements were carried out using Chemito 2500 UV-visible spectrophotometer with an accuracy of ± 0.001 unit. The components of FBX dosimetric solution after preparation were kept in dark for one day. These were mixed on the day when irradiation was given. After irradiation, the measurements were carried out immediately. For each position, five

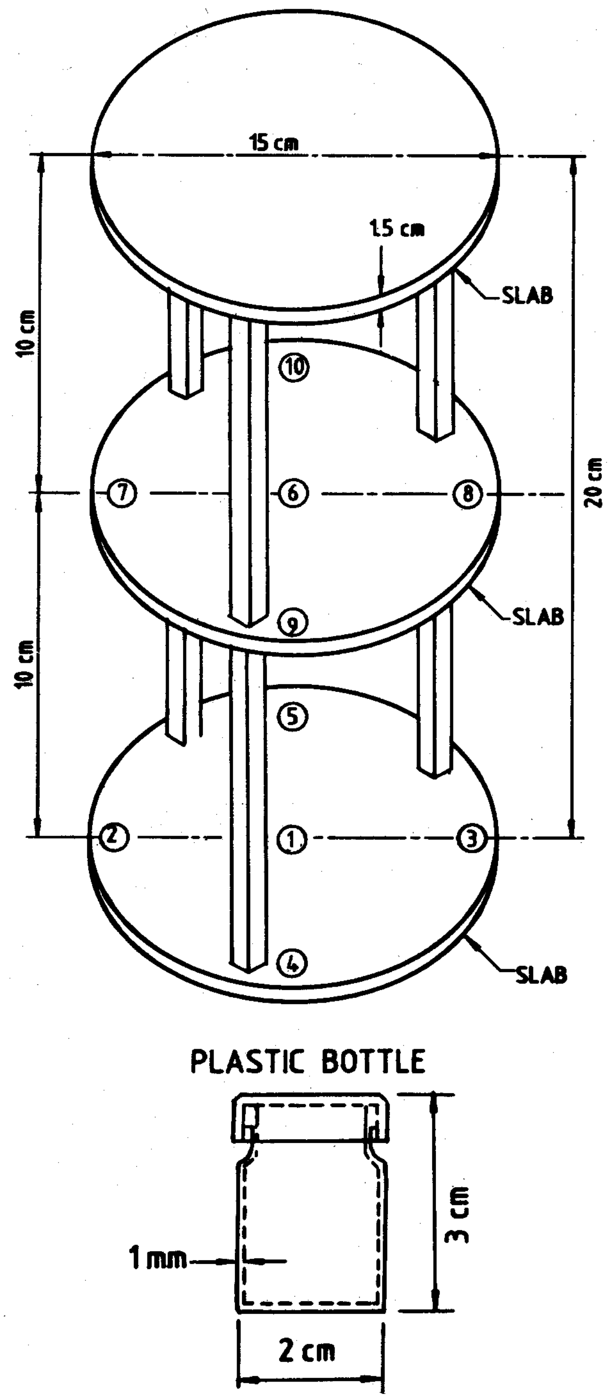

Figure 2. Schematic of the polystyrene phantom (numbers indicate position of the dosimeters).

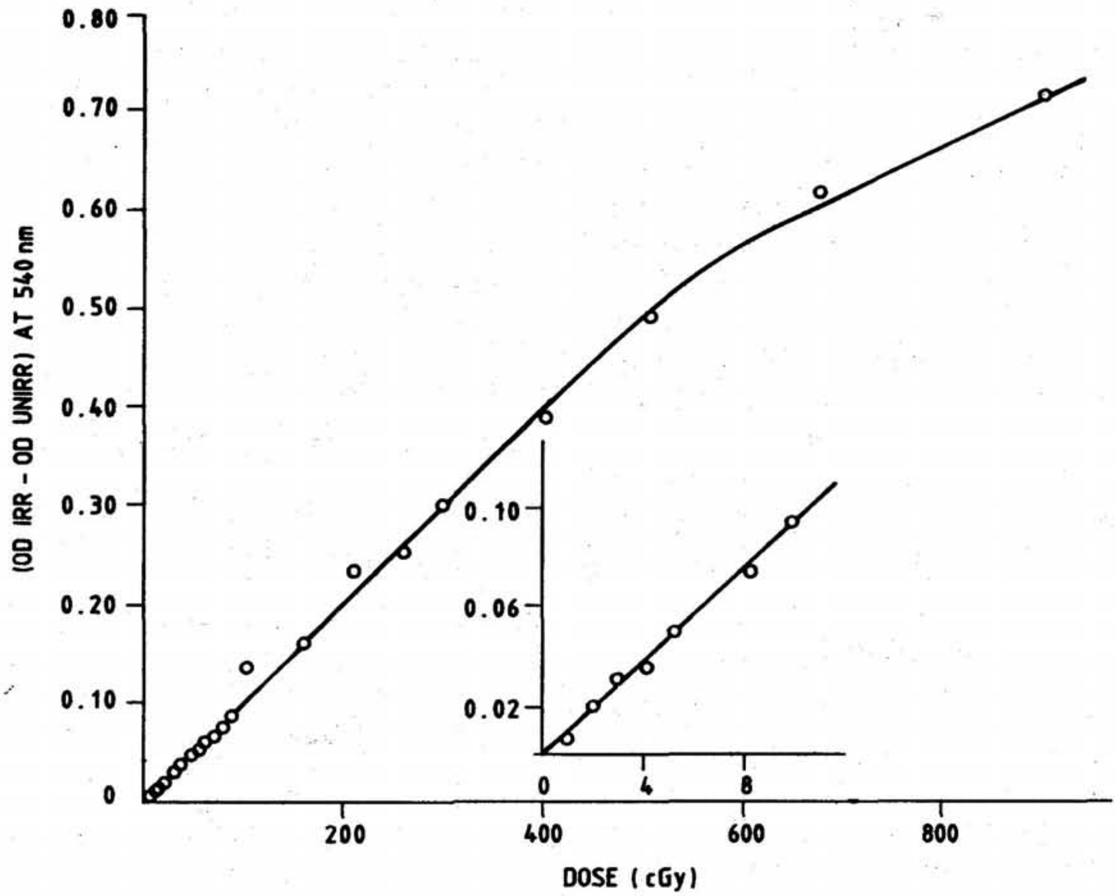

Figure 3. Response curves as a function of absorbed dose. 5 cm cuvette was used to measure low dose (insert curve).

samples were kept and their doses tabulated. From these values, an average dose along with standard deviation (S.D.) was obtained.

3. RESULTS

A linear plot has been obtained for $\Delta A_{540\,nm}$ versus dose (Gy) for FBX system up to 4 Gy. By using a 5 cm cuvette, the lowest dose that could be measured was 0.01 Gy (Fig. 3). For a total absorbed dose of 3 Gy, the dose distribution in the two racks of the polystyrene phantom is given in Table 1. The absorbed doses at different positions of the two racks are given below:

Position I

First rack	2.88 Gy
Second rack	2.97 Gy

Position II

First rack	3.01 Gy
Second rack	2.97 Gy

Position III

First rack	3.11 Gy
Second rack	3.13 Gy

Position IV

First rack	3.15 Gy
Second rack	3.14 Gy

So, positionwise the percentage variation in absorbed dose are 3.13 per cent, 0.67 per cent, 0.67 per cent and 0.31 per cent for positions I, II, III and IV, respectively. The percentage variation of each set, *i.e.*, first and fifth, second and sixth, third and seventh and fourth and eighth from theoretical values were 2.74 per cent, 0.33 per cent, 4.00 per cent and 4.83 per cent, respectively.

Table 1. Doses received by dosimeters kept at different places in the exposure chamber of Gamma Cell. Dose-3 Gy (dose rate: 0.021 to 0.0205 Gy/s)

Position of dosimeter	Sample number	Dose (Gy)	Average dose (Gy) ± (S.D.)
	1	2.50	
	2	2.75	
1	3	3.05	2.88 ± 0.37
	4	2.97	
	5	3.15	
	1	2.80	
	2	3.15	
2	3	2.90	3.01 ± 0.15
	4	3.10	
	5	3.10	
	1	3.00	
	2	3.20	
3	3	2.85	3.11 ± 0.20
	4	3.25	
	5	3.25	
	1	2.95	
	2	3.25	
4	3	3.25	3.15 ± 0.09
	4	3.50	
	5	2.98	
	1	2.95	
	2	2.90	
5	3	3.00	2.97 ± 0.08
	4	2.98	
	5	3.00	
	1	2.90	
	2	3.05	
6	3	2.90	2.99 ± 0.04
	4	3.10	
	5	3.00	
	1	3.00	
	2	3.20	
7	3	3.22	3.13 ± 0.07
	4	3.15	
	5	3.10	
	1	3.00	
	2	3.25	
8	3	3.05	3.14 ± 0.09
	4	3.20	
	5	3.20	

4. DISCUSSION

Absorbance measurements were linear in the lower dose range up to 0.1 Gy, and up to 4 Gy in the higher dose range (Fig. 3). This calibration curve has been used for the measurement of unknown doses with the dosimetric solutions. Percentage composition by weight of elements in FBX dosimetric system and a tissue-equivalent medium[16] are given below:

Elements	FBX (per cent)	Tissue-equivalent medium (per cent)
C	0.0495	12.0
N	3.5011	3.6
O	88.7823	74.2
H	11.0836	10.2
S	0.0821	0.0

The variations in absorbed dose in the two racks are found along the circumference. The extent of individual variation for each position may be due to: (i) variation in extinction coefficient with temperature[17], (ii) different experimental sets of solutions, (iii) personal error during measurement of different sets, etc. But overall, the maximum percentage variation from theoretical value (i.e., 3 Gy) to experimental value is 4.83 per cent. It has been reported that this dosimeter can be used for dosimetry of high energy photons and electrons[18]. Moreover, it can be used on a routine basis for dose estimation for clinical doses in total-body irradiations in radiation therapy, nuclear accidents and brachytherapy.

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