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Importance of sample rotation in BI-2000 during irradiation for dose uniformity improvement

Sachin G. V. Mhatre* and S.H. Shinde

**Radiation Safety Systems Division,
Bhabha Atomic Research Centre, Trombay, Mumbai- 400 085,India**

Corres. Author: sachingvm21@yahoo.com

Abstract: In-order to emphasize the importance of sample rotation during irradiation in BI 2000, relative percentage dose profile measurements were carried out using FBX dosimeters placed in the central vertical plane of the irradiation volume, either using sample rotation facility or kept stationary. Results obtained were further intercompared with that of Fricke system under identical irradiation conditions. Difference between the maximum and minimum relative percentage dose as obtained for stationary and rotating conditions as measured by both the systems was found to be 32.0% and 27.5% respectively.
Key words: Dose mapping, Fricke dosimeter, FBX dosimeter, Blood Irradiator, Dosimetry.

1. Introduction

Blood Irradiator 2000 i.e. BI 2000 belonging to Radiation Biology and Health Science Division of BARC is mainly used for R&D purpose. Assurance that the biological samples are properly irradiated is very crucial for the end results of the research carried out; hence proper dosimetry of blood irradiator is of utmost importance. Ferrous sulphate – Benzoic acid – Xylenol orange i.e. FBX dosimeter is a dosimetry system capable of measuring low doses directly in water1. FBX was earlier successfully used for Blood Irradiation dosimetry[2]

Aim of the present work was to emphasize the importance of sample rotation during irradiation in BI 2000. Hence relative percentage dose profile measurements were carried out under conditions wherein FBX dosimeters placed in the central vertical plane of the irradiation volume, were either rotated using sample rotation facility or kept stationary. Results obtained were further intercompared with that of Fricke system under identical irradiation conditions.

2. Experimental

2.1 Reagents

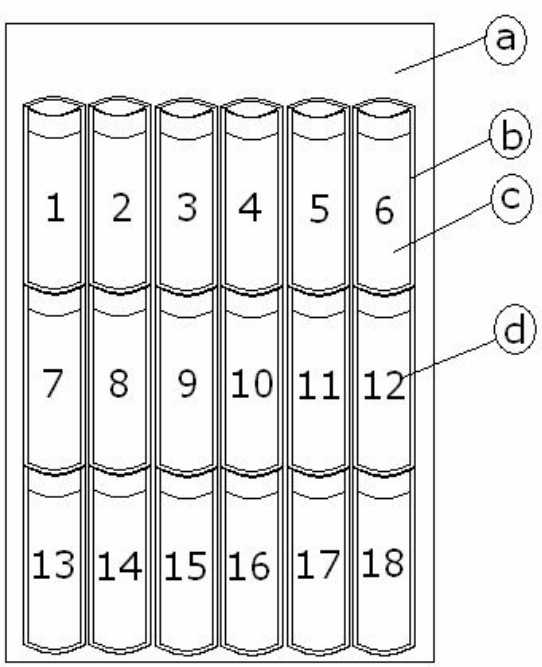
Ferrous ammonium sulphate, sodium chloride, benzoic acid and sulphuric acid were of analytical reagent grade. Xylenol orange obtained from Loba Chemie was used without further purification. Singly distilled water was used for the preparation of FBX and Fricke solution.

2.2 Dosimeter preparation

FBX solution was prepared as per the recommended procedure[1]. ASTM standard practice was followed for use of the Fricke dosimeter[3]. The dosimeter solutions were filled in pre-cleaned polypropylene tubes of 54mm height, 13mm outer diameter and 1mm wall thickness. Cleaning of polypropylene tubes prior to use was carried out as per the recommended procedure[4].

2.3 Irradiation setup

Blood Irradiator 2000 manufactured by Board of Radiation Isotopes and Technology; uses Cobalt-60 as the source and has a rotating turntable for uniform delivery of dose. Dimension of irradiation volume is 130mm diameter and 217mm height. For dose mapping within the irradiation volume, polypropylene tubes filled with FBX dosimeter were arranged in 18 – point grid along the central plane of irradiation volume using a perspex jig to reproduce the geometry, as shown in Fig.1.



a→ Irradiation volume b→ Irradiation jig
c→Dosimeter d→Dosimeter position

Fig.1: Placement of dosimeters along the central vertical plane of irradiation volume of BI 2000 for dose mapping

Similarly Fricke dosimeters were also irradiated. Proper build-up was provided to all the dosimeters during irradiation[5]. FBX and Fricke dosimeters were irradiated for different timings depending upon the dose range of corresponding dosimeters. Digital quartz stopwatch was used to monitor the irradiation time.

2.4 Spectrophotometric measurements

Jasco V-530 UV/Vis double beam spectrophotometer calibrated as per the recommended procedure[6] was used for absorbance measurements. Absorbance measurements and dose estimations of FBX and Fricke dosimeters were carried out as per recommended procedures [1,3].

3. Results and discussions

Fig.1 illustrates the arrangement of polypropylene tubes filled with FBX dosimeter in 18 point grid along the central vertical plane using the jig to reproduce the geometry for dose mapping within the irradiation volume. In all, two sets of dosimeters were used; each set was irradiated for 2 minutes. Average of dose values at each position obtained from these two sets was considered to get the final relative percentage dose profile within the irradiation volume. Dose values were normalized with respect to dosimeter positions 9 and 10, as the difference in dose values obtained from these positions was within ±1%. Table 1 shows the relative percentage dose profile within the irradiation volume of Blood Irradiator 2000, as measured by FBX dosimeter. Sample rotation facility was not used during this exercise.

Relative percentage dose profile measured by FBX dosimeters was further confirmed using Fricke dosimeter, which is a reference standard dosimeter. Fricke dosimeters were irradiated using the same jig along the central vertical plane of the irradiation volume, similar to that of FBX dosimeters. Fricke dosimeters were irradiated for 30 minutes. As Fricke dosimeter is less sensitive compared to FBX dosimeter, irradiation time required to deliver a suitable dose was comparatively large. Table 1 shows the relative percentage dose profile within the irradiation volume of Blood Irradiator 2000, as measured by Fricke dosimeters. Table 2 shows the relative percentage dose profile within the irradiation volume of Blood Irradiator 2000, as measured by FBX and Fricke dosimeters, using the sample rotation facility providing 60 rotations per minute.

Table 1: Percentage dose distribution measured by FBX & Fricke dosimeters (Sample rotation facility not used)

Dosimeter position	Percentage dose values as measured by		FBX / Fricke
	FBX	Fricke	
1	103	104	0.99
2	92	93	0.99
3	89	88	1.01
4	88	87	1.01
5	94	95	0.99
6	113	112	1.01
7	118	118	1.00
8	107	105	1.02
9	100	100	1.00
10	100	100	1.00
11	106	106	1.00
12	119	120	0.99
13	111	112	0.99
14	99	97	1.02
15	92	92	1.00
16	92	91	1.01
17	97	96	1.01
18	110	112	0.98

Table 2: Percentage dose distribution measured by FBX & Fricke dosimeters (Sample rotation facility used)

Dosimeter position	Percentage dose values as measured by		FBX / Fricke
	FBX	Fricke	
1	107	105	1.02
2	93	93	1.00
3	90	90	1.00
4	90	89	1.01
5	93	94	0.99
6	109	108	1.01
7	116	116	1.00
8	105	107	0.98
9	100	100	1.00
10	100	100	1.00
11	104	105	0.99
12	117	117	1.00
13	110	109	1.01
14	98	97	1.01
15	92	91	1.01
16	93	94	0.99
17	97	97	1.00
18	110	110	1.00

Agreement between dose profiles measured by FBX and Fricke dosimeters were within ± 2%. This agreement verifies the dose profile pattern in irradiation volume as measured by two redundant independent dosimetry systems. Difference between the relative percentage maximum and minimum dose as obtained from the FBX and Fricke dosimeters was found to be 32.0% and 27.5% for stationary and rotating conditions respectively. These results clearly indicate improved dose uniformity for the samples rotated during irradiation in BI-2000. Hence it is recommended that for irradiation of samples occupying the entire irradiation volume, the sample should be rotated using the sample rotation facility to get a better dose uniformity.

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