Studies on Reduction of Dosimeter Used In the Product Dose Mapping Process at Sinagama Plant

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Abstrak

Pemetaan dos produk merupakan suatu kaedah yang mana konfigurasi susun atur produk yang terbaik dikenalpasti bagi kegunaan sewaktu proses pensterilan rutin. Dalam pemetaan dos produk, dosimeter akan ditempatkan di lokasi strategik pada produk bagi tujuan mengenalpasti kawasan yang terdedah pada dos maksimum dan minimum. Pada kaedah pemetaan dos produk yang terdahulu, Sinagama telah menggunakan sebanyak 240 unit dosimeter untuk 1 tote. Berdasarkan data yang diperolehi dari laporan Pemetaan Dos Alat Penyinaran Sinagama pada tahun 2004 dan sokongan data ujikaji terbaru, bilangan dosimeter yang digunakan dalam proses pemetaan dos produk boleh dikurangkan kepada 28 unit tanpa mengorbankan kepersisan dan ketepatan keputusan pemetaan dos. Ini turut membawa kepada pertukaran kaedah menempatkan dosimeter, iaitu dari sistem satah kepada sistem koordinat. Penggurangan sebanyak 88% ke atas penggunaan dosimeter secara langsung akan menyumbang kepada penggurangan perbelanjaan ke atas dosimeter, masa dan tenaga kerja.

Abstract

Product dose mapping is the determination of the best product loading configuration which will be used during routine sterilization. In product dose mapping, dosimeters are placed throughout products at strategic locations to determine the zones of minimum and maximum dose. On previous Sinagama's product dose mapping method, a total of 240 unit's ceric-cerous dosimeter been used for a tote. Based on the data obtained from Irradiator Dose Mapping Report in 2004 and data from recent studies, the number of dosimeter to be used in product dose mapping can be reduced to 28 units without sacrificing precision and accuracy of the dose mapping results. This also led changes of the placing dosimeter method from Plane system to Coordinate system. Reduction of 88% on dosimeters usage will directly reduce the cost of expenses on dosimeter, time and labor.

Keywords: Dose mapping, dosimeter, Sinagama

INTRODUCTION

Process qualification entails product dose mapping a particular product and/or group of products. Product dose mapping is the determination of the loading configuration which will be used during routine sterilization. In product dose mapping, dosimeters are placed throughout products at strategic locations to determine the zones of minimum and maximum dose. Product dose mapping yields the following results:

- A max to min ratio which is the ratio of the maximum dose to minimum dose contained within the product
- The establishment of a tote loading pattern to be used during routine processing
- Establishment of the mathematical correlation between the dose at the Standard Monitoring Position and doses within the actual product boxes.

On regular Sinagama's product dose mapping activities, a total of 240 unit's ceric-cerous dosimeter been used for a tote. The operator would place dosimeters all over the tote in a three dimensional pattern. The dosimeters are read at the end of processing to ensure customers product has received the amount of radiation required.

Based on the Sinagama's Irradiator Dose Mapping Report (Refer to Table 1 and Table 2) done on 5 to 6 April 2004 by Secondary Standard Dosimetry Laboratory (SSDL), potential areas where the maximum dose (D_{max}) and minimum dose (D_{min}) reached during the irradiation of products were identified.

Table 1. Analysis of Dose Distribution in the Tote 9, 10 and 11 Using Ceric-Cerous Dosimeter for Radiation of High-Density Products

Tote No.	Maximum Dose (D_{max})		Minimum Dose (D_{min})		Uniformity Ratio
	Position	Dose (kGy)	Position	Dos (kGy)	Dos (U), $U=D_{max}/D_{min}$
9	7-E-4	39.5	0-C-1	26.9	1.47
10	11-E-5	39.1	1-C-1	27.0	1.45
11	2-E-3	38.2	1-C-1	26.8	1.43
Average		38.9		26.9	1.45

Table 2. Analysis of Dose Distribution in the Tote 9, 10 and 11 Using Ceric-Cerous Dosimeter for Radiation of Low Density Products

Tote No.	Maximum Dose (D_{max})		Minimum Dose (D_{min})		Uniformity Ratio
	Position	Dose (kGy)	Position	Dos (kGy)	Dos (U), $U=D_{max}/D_{min}$
9	6-A-3	34.8	5-C-1	26.5	1.31
10	6-A-2	37.1	15-C-1	27.2	1.36
11	3-A-5	37.9	15-C-1	27.5	1.38
Average		36.6		27.1	1.35

Thus all the data for the maximum and minimum dose obtained from the dose mapping report done by SSDL can be used to monitor and predict the position of the maximum and minimum dose to be received all over the tote during the irradiation of products.

OBJECTIVES

To reduce the number of dosimeter used in the product dose mapping activity, 225 units to a minimum amount possible without sacrificing precision and accuracy of the dose mapping results.

MATERIAL AND METHODS

Dummies utilized in this experiment was 12 boxes of low density polystyrene, while the dosimeter used is low dose Ceric-cerious B16/11 supplied by SSDL.

Unlike previous method that used Plane system (Figure 1), this experiment will use a new method in order to parallel with U.S. Department of Agriculture - Animal and Plant Health Inspection Service (USDA – APHIS) method, which is Coordinate system (Figure 2).

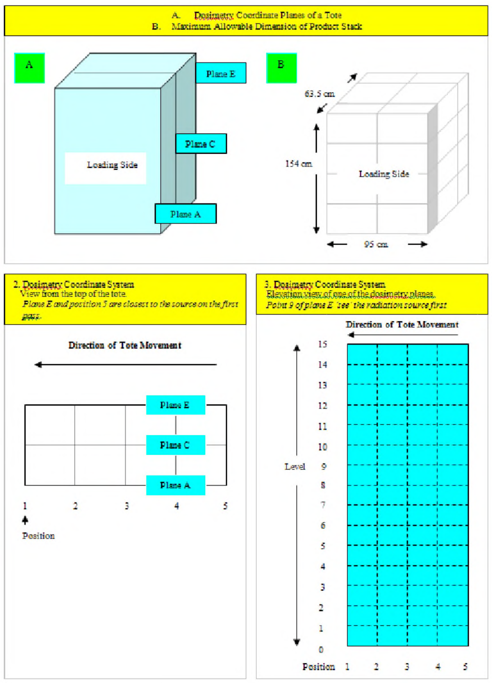

Figure 1: Plane System A, C and E

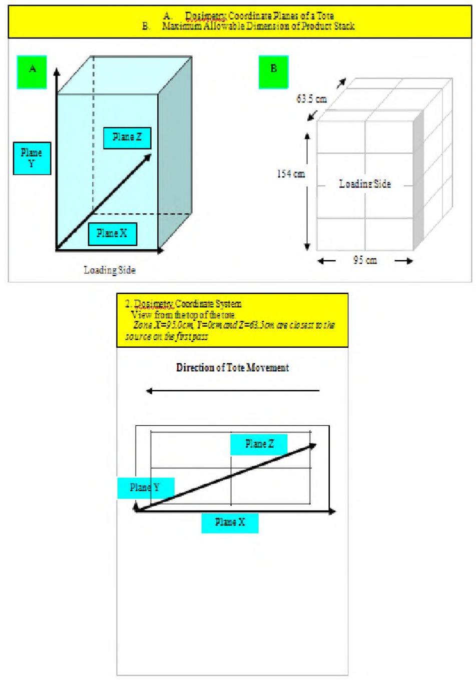

Figure 2: Coordinate System

Data of maximum and minimum dose position from Table 1 and Table 2 were first converted to coordinate system (Table 3 and Table 4).

Tote No.	Maximum Dose (D_{max})		Minimum Dose (D_{min})	
	Plane System	Coordinate System	Plane System	Coordinate System
9	7-E-4	X= 71.3 Y= 70.0 Z= 63.5	0-C-1	X= 0 Y= 0 Z= 32.0
10	11-E-5	X= 95.0 Y= 110.0 Z= 63.5	1-C-1	X= 0 Y= 10.0 Z= 32.0
11	2-E-3	X= 48.0 Y= 20.0 Z= 63.5	1-C-1	X= 0 Y= 10.0 Z= 32.0

Table 3. Analysis of Dose Distribution in the Tote 9, 10 And 11 Using Ceric-Cerous Dosimeter for Radiation of High Density Products

Tote No.	Maximum Dose (D_{max})		Minimum Dose (D_{min})	
	Plane System	Coordinate System	Plane System	Coordinate System
9	6-A-3	X= 48.0 Y= 60.0 Z= 0	5-C-1	X= 0 Y= 50.0 Z= 32.0
10	6-A-2	X= 23.8 Y= 60.0 Z= 0	15-C-1	X= 0 Y= 150.0 Z= 32.0
11	3-A-5	X= 95.0 Y= 30.0 Z= 0	15-C-1	X= 0 Y= 150.0 Z= 32.0

Table 4. Analysis of Dose Distribution in the Tote 9, 10 And 11 Using Ceric-Cerous Dosimeter for Radiation of Low Density Products

All the D_{max} and D_{min} from Table 3 and Table 4 then illustrate into Figure 3 to obtain a clearer picture of the D_{max} and D_{min} achieved.

Based on the identified areas that potentially can achieve D_{max} and D_{min}, only 28 units dosimeter proposed to be used for dose measurements for one tote. Each dosimeter will be placed at the area (specific coordinate) that is potentially exposed to the maximum and minimum dose. The coordinates of the dosimeter placement proposed were shown in Table 5.

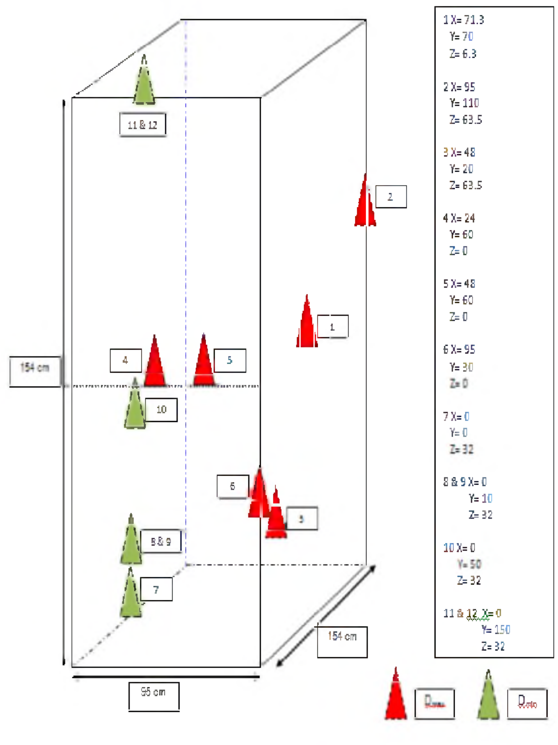

Figure 3: Position of D_{max} and D_{min} in Tote

Zone	X (cm)	Y (cm)	Z (cm)
1	0	150.0	32.0
2	23.8	150.0	32.0
3	48.0	150.0	32.0
4	48.0	110.0	63.5
5	71.3	110.0	63.5
6	95.0	110.0	63.5
7	48.0	70.0	63.5
8	71.3	70.0	63.5
9	95.0	70.0	63.5
10	0	60.0	0
11	23.8	60.0	0
12	48.0	60.0	0
13	0	50.0	32.0
14	23.8	50.0	32.0
15	48.0	50.0	32.0
16	48.0	30.0	0
17	71.3	30.0	0
18	95.0	30.0	0
19	48.0	20.0	63.5
20	71.3	20.0	63.5
21	95.0	20.0	63.5
22	0	10.0	32.0
23	23.8	10	32.0
24	48.0	10	32.0
25	0	0	32.0
26	23.8	0	32.0
27	48.0	0	32.0
*28	95	0	63.5

* 28: Position the control dosimeter; coordinates are closest to the source of Co-60

Table 5: Coordinates for Dosimeter Placement

12 boxes of dummies then loaded into 154 x 95 x 63.5 cm tote (total weight: 22.800 g, volume: 972,085.5 cm^3, density: 0.02 g/cm^3) and then 268 dosimeters were placed (240 dosimeters from original method and 28 dosimeters from new method were placed side by side) according to the arrangement in Figure 1 and Table 5. Tote then brought into the irradiation room for irradiated at 5 kGy dose. After the irradiation process is complete, all dosimeter collected and analyzed at the Sinagama's Dosimetry laboratory.

DISCUSSION

For product dose mapping purpose, a total of 240 unit's ceric-cerous dosimeter will be used. Based on the data obtained from Irradiator Dose Mapping Report issued by SSDL in 2004, the number of dosimeter to be used in the process of dose mapping can be reduced to 28 units. This also led changes of the method of placing dosimeter from Plane system to Coordinate system.

Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy
0-A-1	9.0	5.7	0-A-2	8.4	5.4	0-A-3	8.6	5.5	0-A-4	8.6	5.5	0-A-5	8.8	5.6
1-A-1	9.5	6	1-A-2	9.1	5.8	1-A-3	10.4	6.6	1-A-4	9.4	6	1-A-5	9	5.7
2-A-1	9.1	5.8	2-A-2	9.1	5.8	2-A-3	9.3	5.9	2-A-4	9.5	6	2-A-5	9.1	5.8
3-A-1	9.3	5.9	3-A-2	9.2	5.8	3-A-3 16	9.3	5.9	3-A-4 17	9.6	6.1	3-A-5 18	9.2	5.8
4-A-1	9	5.7	4-A-2	8.9	5.7	4-A-3	9.5	6	4-A-4	9	5.7	4-A-5	9.3	5.9
5-A-1	8.9	5.7	5-A-2	9	5.7	5-A-3	9.2	5.8	5-A-4	9.2	5.8	5-A-5	9.4	6
6-A-1 10	8.7	5.5	6-A-2 11	9.2	5.8	6-A-3 12	9.1	5.8	6-A-4	8.9	5.7	6-A-5	9.4	6
7-A-1	9	5.7	7-A-2	9.1	5.8	7-A-3	9.3	5.9	7-A-4	9.4	6	7-A-5	9.6	6.1
8-A-1	9.1	5.8	8-A-2	9.1	5.8	8-A-3	9.1	5.8	8-A-4	9	5.7	8-A-5	8.8	5.6
9-A-1	9.3	5.9	9-A-2	9.1	5.8	9-A-3	9	5.7	9-A-4	9.1	5.8	9-A-5	9.3	5.9
10-A-1	8.9	5.7	10-A-2	9.1	5.8	10-A-3	9.1	5.8	10-A-4	9.1	5.8	10-A-5	8.9	5.7
11-A-1	9.4	6	11-A-2	9.5	6	11-A-3	9.3	5.9	11-A-4	9	5.7	11-A-5	8.9	5.7
12-A-1	9.4	6	12-A-2	9.8	6.2	12-A-3	9.4	6	12-A-4	9.5	6	12-A-5	9.6	6.1
13-A-1	9.2	5.8	13-A-2	9.6	6.1	13-A-3	9.4	6	13-A-4	9.3	5.9	13-A-5	9.3	5.9
14-A-1	8.9	5.7	14-A-2	8.7	5.5	14-A-3	8.8	5.6	14-A-4	9.2	5.8	14-A-5	9	5.7

Plane A

Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy
0-C-1 25	7.3	4.7	0-C-2 26	8	5.1	0-C-3 27	8.2	5.2	0-C-4	8.4	5.4	0-C-5	7.4	4.7
1-C-1 22	8.1	5.2	1-C-2 23	8.1	5.2	1-C-3 24	7.8	5	1-C-4	8.3	5.3	1-C-5	7.9	5.1
2-C-1	7.7	4.9	1-C-2	8.1	5.2	1-C-3	8.1	5.2	1-C-4	8.8	5.6	1-C-5	8.8	5.6
3-C-1	7.8	5	3-C-2	8.9	5.7	3-C-3	8.4	5.4	3-C-4	8.5	5.4	3-C-5	8.6	5.5
4-C-1	8.2	5.2	4-C-2	8.2	5.2	4-C-3	8.2	5.2	4-C-4	8.5	5.4	4-C-5	8.1	5.2
5-C-1 13	12.1	7.6	5-C-2 14	8.4	5.4	5-C-3 15	8.3	5.3	5-C-4	8.1	5.2	5-C-5	8	5.1
6-C-1	8.1	5.2	6-C-2	8.5	5.4	6-C-3	8.3	5.3	6-C-4	8.4	5.4	6-C-5	8.3	5.3
7-C-1	8.9	5.7	7-C-2	8.7	5.5	7-C-3	8.6	5.5	7-C-4	8.8	5.6	7-C-5	8.3	5.3
8-C-1	8.2	5.2	8-C-2	8.6	5.5	8-C-3	8.5	5.4	8-C-4	8.9	5.7	8-C-5	8.4	5.4
9-C-1	8	5.1	9-C-2	8.1	5.2	9-C-3	8.3	5.3	9-C-4	8.4	5.4	9-C-5	8.4	5.4
10-C-1	8.1	5.2	10-C-2	8.5	5.4	10-C-3	8.5	5.4	10-C-4	8.7	5.5	10-C-5	8.4	5.4
11-C-1	8	5.1	11-C-2	8.5	5.4	11-C-3	8.8	5.6	11-C-4	8.5	5.4	11-C-5	7.9	5.1
12-C-1	8.2	5.2	12-C-2	8.3	5.3	12-C-3	8.2	5.2	12-C-4	8.4	5.4	12-C-5	8.2	5.2
13-C-1	8	5.1	13-C-2	8	5.1	13-C-3	8.3	5.3	13-C-4	8.4	5.4	13-C-5	8.2	5.2
14-C-1 1	7.8	5	14-C-2 2	7.8	5	14-C-3 3	8.1	5.2	14-C-4	8	5.1	14-C-5	8.3	5.3

Plane C

Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy	Position	mV	kGy
0-E-1	8.7	5.5	0-E-2	8.6	5.5	0-E-3	8.4	5.4	0-E-4	8.2	5.2	0-E	8.2	5.2
1-E-1	8.6	5.5	1-E-2	9.4	6	1-E-3	9.8	5.6	1-E-4	12.5		1-E-5	8.9	5.6
2-E-1	8.7	5.5	2-E-2	9.1	5.8	2-E-3 19	9.2	5.8	2-E-4 20	9.1	5.8	2-E-5 21	8.7	5.5
3-E-1	8.8	5.6	3-E-2	9.8	6.2	3-E-3	9	5.7	3-E-4	9.5	6	3-E-5	10.9	6.8
4-E-1	8.6	5.5	4-E-2	8.9	5.7	4-E-3	9.4	6	4-E-4	9.1	5.8	4-E-5	9	5.7
5-E-1	8.3	5.3	5-E-2	8.9	5.7	5-E-3	8.9	5.7	5-E-4	9	5.7	5-E-5	9.3	5.9
6-E-1	8.4	5.4	6-E-2	8.9	5.7	6-E-3	8.8	5.6	6-E-4	8.7	5.5	6-E-5	8.7	5.5
7-E-1	8.6	5.5	7-E-2	8.9	5.7	7-E-3 7	9	5.7	7-E-4 8	8.7	5.5	7-E-5 9	9.1	5.8
8-E-1	9	5.7	8-E-2	9.1	5.8	8-E-3	9.1	5.8	9-E-4	8.9	5.7	8-E-5	8.8	5.6
9-E-1	9	5.7	9-E-2	9.3	5.9	9-E-3	9	5.7	9-E-4	8.9	5.7	9-E-5	9	5.7
10-E-1	9	5.7	10-E-2	8.8	5.6	10-E-3	9	5.7	10-E-4	8.8	5.6	10-E-5	8.5	5.4
11-E-1	8.4	5.4	11-E-2	9	5.7	11-E-3 4	9.1	5.8	11-E-4 5	9.1	5.8	11-E-5 6	8.6	5.5
12-E-1	8.5	5.4	12-E-2	8.9	5.7	12-E-3	9.7	6.2	12-E-4	9.3	5.9	12-E-5	9.3	5.9
13-E-1	9	5.7	13-E-2	8.9	5.7	13-E-3	9.9	5.7	13-E-4	9.2	5.8	13-E-5	9	5.7
14-E-1	8.1	5.2	14-E-2	8.7	5.5	14-E-3	9.9	6.3	14-E-4	8.9	5.7	14-E-5	8.6	5.5

Plane E

Coordinate system   Plane system

Table 6: Comparison of Dose Distribution in the Tote Using Two Type of Dosimeter Placement System

Analysis on dose distribution in the tote using two different method of dosimeter placement system is shown in Table 6. Based on the data analysis, both method recorded the maximum dose obtained was 7.6 kGy and located at position 5-C-1 on the plane system or position 13 on the coordinate system. Minimum dose obtained was 4.7 kGy and located at two positions, 0-C-1 and 0-C-5 on the plane system or position 25 only on the coordinate system.

Dose uniformity ratio (DUR) for irradiation of products with 0.02 gm/cm^3 density is:

$$\begin{aligned} DUR &= D_{max}/ D_{min} \\ &= 7.6/4.7 \\ &= 1.62 \end{aligned}$$

CONCLUSION

The number of dosimeter used in the product dose mapping process can be reduce from 240 to 28 units by placing the dosimeter in areas that have been identified potentially expose to maximum and minimum dose. This also led to changes of the placing dosimeter method from Plane system to Coordinate system. Reduction of 88% on dosimeters usage will directly reduce the cost of Sinagama expenses on dosimeter, time and labor.

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