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The Study of Dose Distribution in The Irradiated Material

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Abstract
Irradiation method, dose determination and dose distribution through all the irradiated products are treated in this paper. The absorbed dose is determined using calibrated ECB dosimeters. For dose distribution of ECB dosimeters is used oscillometry method in combination with ionization chamber. Dose uniformity is calculated as the rate of minimal and maximal dose absorbed in the irradiated product. The process of irradiation is realized by rotation of the vessel where the material is put. The dose uniformity for the used method is 81%. Dose in the irradiated product is determined as the absorbed dose in the ECB dosimeter.

Keywords: ECB dosimeter, Ionization chamber, Oscillotitrator, Cs-137 gamma irradiation source

INTRODUCTION

Absorbed dose is the key parameter that determines final characteristics of irradiated product. It is important to have a good precision in the measurement of dose in a "point "of irradiated product. Also is of great importance the study of dose distribution along the product volume. This last one measure minimal dose and maximal absorbed dose in the material. Doses D_{min} and D_{max} must be within an interval that provide achievement of the desired result. It's evident that D_{min}/D_{max} rate which determines irradiation uniformity, must be as near as the value one, notably in scientific studies, because that experimental results will represent the dose-effect link. Exact measurement of dose is determined by dosimetric system used, while an appropriate irradiaton technic and geometry provides a satisfactory uniformity distribution of irradiated material.

MATERIALS AND METHODS

For irradiation of dosimeters and materials it was used gamma irradiator GU-3 with Cs-137 source. As absolute dosimeter was used irradiation chamber M 23331 (both with its metering equipment rate meter DL4) and as routine dosimeter was used Ethanol Chlorobenzene dosimeter (ECB). This last one is a closed glass ampule with diameter 10.80 mm ± 0.01 mm and wall thickness 0.6 mm, enough to realize electronic balance.

For dose determination in ECB dosimeters, as a method, was used oscillometric method, exploiting OK -302/2 oscillotitrator for measuring dosimeter response. During irradiation of material with a certain volume, it is very important to determine minimal and maximal dose areas and to find such an irradiation technic, to provide a very good uniformity of dose distribution in material. Based on building design of gamma irradiator GU-3, as irradiation geometry was chosen that indicated in figure 1a-b, while as irradiation technic was used that with rotation placing dosimeters in a copper wire profile with 2 mm diameter.

This technic provides a very good uniformity of absorbed dose comparing with other technics used till now Dodbiba A. (2000, 2002). For a very good determination of dose distribution in the material volume to be irradiated, inside the volume must be placed a great number of dosimeters. Referred to previous studies, taking into consideration absorbed dose symmetry around rotational central axis of dish 2/2, in the wire copper profile were placed four dosimeters A, B, C and D instead of ten dosimeters used in Dodbiba A. et. Al. (2002, 2001) (Fig. 1b).

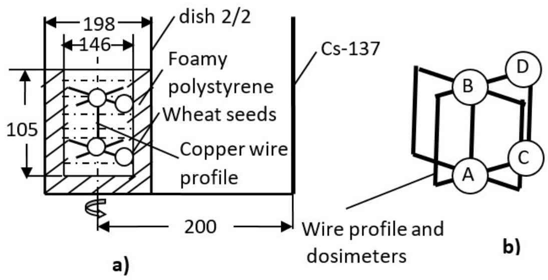

Figure 1. Geometry and irradiation technic

Before irradiation of real material was done a simulation of irradiation process Dodbiba. A et. al (2001). As simulated material was used soft wheat, which is thrown in dish 2/2 in an equal volume with that of real material that will be used for an irradiation (Fig. 1a).

Dosimeters A, B, C and D are chosen by the series of dosimeters preliminary calibrated, according to the method given on Hasa M. (2009). Dosimeters were irradiated (with technic and geometry indicated in fig 1 a and b for a period of 48 hours. After irradiation dosimeters were measured in the oscillotitrator OK-302/2, with the same method and parameters measuring equipment, as well as in the case of dosimeters set used for calibration.

RESULTS AND DISCUSSION

Measurement dates for dosimeters reading A, B, C, D and for absorbed dose, calculated referred curves equaitions given in figure 2 and figure 3, are given in table 1 and table 2.

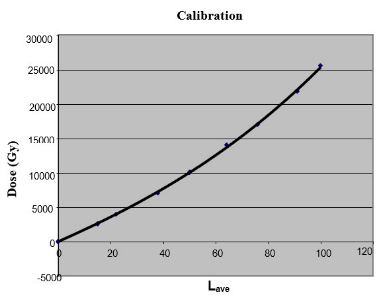

Figure 2. Calibration curve for doses range (0÷25578) Gy

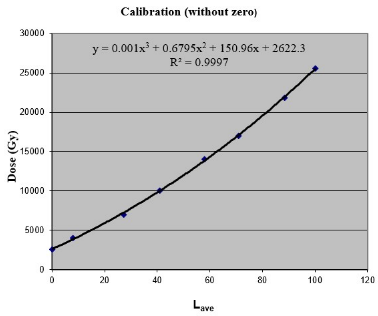

Figure 3. Calibration curve for dose range (2584.75 ÷ 25578) Gy

Table 1. Dates calculated according to the graphic in figure 2

Dosimeter	Reading L	L_{ave}	$L_{c\ ave}$	D (Gy)	D_{return} (Gy)	U_1 (%)	U_2 (%)
A	51.5 51.7 51.3 51.8	51.8	51.9	10484	11790		
B	62 62 62 61.7	61.9	62	13095	11790	67	81
C	63.5 63.7 64 63.8	63.7	63.8	13586	14609		
D	71 70.5 71 71.3	70.9	71	15632	14609		
S_m	50.1 49.8 50.1 50	50					
P_{ave}= 4.58 Gy/min							

Table 2. Dates calculated according to the graphic in figure 3

Dosimeter	Reading L	L_{ave}	$L_{c\ ave}$	D (Gy)	D_{return} (Gy)	U_1 (%)	U_2 (%)
A	43 42.8 42.9 42.9	42.8	42.4	10321	11568		
B	54 54.3 54.4 54.9	54.4	53.8	12815	11568	65	79
C	57.5 57.7 57.5 57.8	57.6	56.9	13596	14689		
D	66.5 66.3 66.7 66.7	66.6	65.8	15782	14689		
S_m	58.8 58.3 58.8 58.6	58.6					
P_{ave} = 4.56 Gy/min							

In table 1 and table 2:

L- oscillotitrator reading

L_{ave} – average reading

$L_{c\ ave}$ – average corrected reading

D- absorbed dose (calculated according to the graphic in fig 2 and fig 3)

D_{return} – Return dose

U_1 and U_2 – Uniformity of dose distribution, without return of material and with return of it

Return dose means the fact that dosimeters (material) half of time are irradiated according to placement indicated in figure 1 and the other half time are irradiated changing their positions (A with B and C with D). P_{ave} represents the average power of absorbed dose.

In above table the quantity $L_{c\ ave}$ (average corrected reading) is calculated by the equation :

$$L_{c\ ave} = L_{ave}\ \frac{S_e}{S_m}$$

where:

S_e - is expected reading for used dosimeter for calibration, whose value is around division 50.

S_m – is the measured reading for this dosimeter (the day when are measured A, B, C and D dosimeters)

The reading value S_e, for the graphic in fig 2, is 50.07, while for the graphic in fig 2 is S_e = 57.9. Referred to Sharpe P., Miller A. (1999) for nonlinear curves extrapolation is not acceptable. Also the dosimeters will not be used to measure doses between zero and the point that represents the smallest dose in the calibration curve (means that zero dose will not be used as calibration point) if it is not known dosimeter behavior in this area.

To see if, it can be used zero point as calibration point, we compared absorbed dose by dosimeters A, B, C and D, calculated according to calibration curves given in fig 2, marked with D_1, with value of doses D_2 calculated according the given curve in fig 3. Dates are given in table 3.

Table 3. Compared absorbed dose by dosimeters A÷D calculated according to calibration curves

Dosimeter	D_1 (Gy) according to fig 2	D_2 (Gy) according to fig. 3	D_1 / D_2 (%)
A	10484	10321	101.6
B	13095	12815	102.2
C	13586	13596	99.9
D	15632	15782	99

By the table 3 it is shown that changes between respective doses D1 and D2 are ≤ 2 %. Taking into consideration the inaccuracy with the used oscillometric method is ± 6%, we can say that practically doses D_1 and D_2 are equal. Also the curve in fig 2 or that presented in fig 3 can be used as calibration curve and zero point as calibration point. Using the technic in fig 1, (for average dose power 4.58 Gy/min and uniformity 81%) are achived positive results for a number of irradiated products, medical (for sterilization) and food (for reduction of total microbial load) Hasa M. (2009).

Main results achived are:

Oscillometric method is simple and fast.

Irradiation technic with rotation provide a power dose by 4.58 Gy/min and a good uniformity of absorbed dose (81%)

Negligible change for calculated doses by to curves, indicates that the two curves can be used as calibration curves and zero point as calibration point.

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