

IMPLEMENTATION OF METHODOLOGY FOR HIGH-DOSE DOSIMETRY

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Abstract: The purpose of this work is to propose the implementation of methodology for high-dose measurements using traceable dosimeters related to the international metrology system, and to establish in the country, a standard for high-dose related to industrial irradiation facilities and research irradiators.

Keywords: Radiation Metrology, Dosimetry, Industrial Irradiation Facilities

1. INTRODUCTION

The industrial irradiation facilities are mainly used for a variety of processing products for different objectives. Among the many uses of radiation processing it can be mentioned: sterilization of medical products, sterilization of pharmaceuticals, treatment of cosmetics, food irradiation, water purification, treatment of industrial waste, polymer degradation, vulcanization, wire insulation, etc. Therefore, in order to reach the desired objectives for each irradiated material there is a range of allocated absorbed dose. Dosimetry has got an important role to transfer the research knowledge into the productive stage. In the food and disposable medical materials, the main thing is to assure the minimum dose to achieve the desired results through the validation processes (D10 Value), which are mandated on these processes. In all procedures related to irradiation processes, there is the need to the process control and validation regarding the objectives of these formal procedures and to supply adequate documentation that confirms the successes of the irradiation process [1-2].

2. PROPOSE

The implementation of a laboratory standard for measuring high-dose requires international traceability. This requirement is based on three reasons: (1) The lack of national high-dose LAB that handles the dissemination of measuring unit and keep international traceability; (2) The not yet effective application of the Mutual Recognition Arrangement, despite the international effort led by CIPM in 1999; (3) The high costs to import dosimeters for Irradiation Facilities.

3. METODOLOGY

The radiation processing key element is undoubtedly a reliable and traceable dosimetry system. It should have been

established a national LAB in this country to provide high-dose measurements without breaking the metrology chain. On the figure 1, it can be seen a suggested metrology chain, dosimeter class and related uncertainties [1-2].

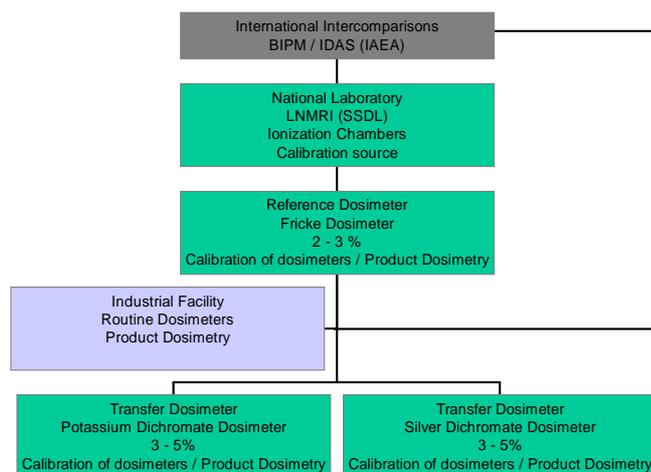


Fig. 1 – Suggested flow-chart for high-dose LAB for traceability

3.1 – Calibration of reference dosimeter

Most of the national LABS apply the Fricke dosimeter as a standard reference for absorbed dose measurements, due to its metrological qualities and low cost.

3.1.1 – Calibration of reference dosimeter at SSDL “Set-Up”.

The source of ⁶⁰Co at the “Laboratório Nacional de Metrologia das Radiações Ionizantes” (LNMRI) a standard secondary dosimetry LAB (SSDL) is used to calibrate the Fricke dosimeters. It has been used in the following set-up: source distance of 1.00 m; irradiation field of 0,10 x 0,10 m²; “Mix-D” dosimeters holder with 3 irradiation positions; Thimble Chamber of 0.6 cc (calibrated at BIPM); electrometer NE (Nuclear Enterprises); Fricke dosimeters (sealed glass ampoules 15 mm diameter and 40 mm of height).

3.1.2 – Calibration of the gammacell “Set-Up”

The reference dosimeter has been used to calibrate the Gammacell irradiator, in dosimeter holder with 5 positions, made in PMMA.

3.2 – Calibration of transfer dosimeters

The silver dichromate dosimeter (1 – 12 kGy) and potassium dichromate dosimeter (5 – 50 kGy) have been calibrated with the Gammacell [3-4].

4. RESULTS

The methodology applied to this work has been based on Mc Laughlin, W.L.; Boyd, A.W.; Chadwick, K.H.; McDonald, J.C.; Miller, A; TR409-IAEA; NIST special publication 250-45 and ISOGUM95 works.

4.1 – Fricke Dosimeter (reference dosimeter)

Twenty-seven dosimeters have been irradiated with doses between 100-350 Gy to build the calibration response curve.

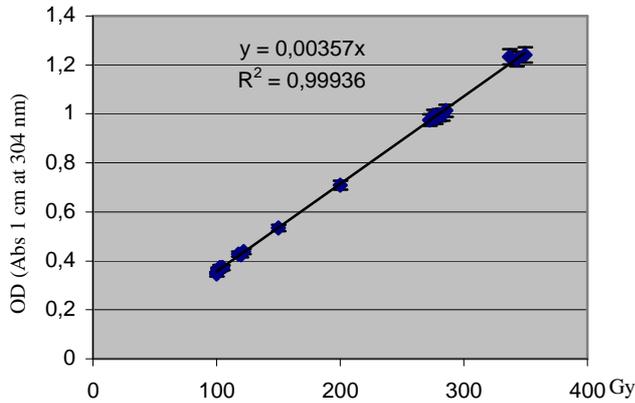


Fig. 2 – Response curve for reference dosimeter (“Fricke”)

$$D_{Fricke} = \frac{281.29\Delta A}{[1+0.007(T-25)][1+0.0015(T'-25)]} (Gy) \quad (1)$$

Where

- D_{Fricke} = Absorbed Dose (Gy)
- ΔA = Change in Absorbance at 304 nm
- T = read-out temperature
- T' = Irradiation temperature

4.1.2 – Uncertainties for reference dosimeter

The value of calibration factor and methodology to be meaningful shall be accompanied by an estimate uncertainty. In this work was used the method of expressing uncertainties as type “A” and type “B” recommended in the “ISO Guide to the Expression of Uncertainty in Measurement” [6].

Table 1 – Uncertainties of Fricke Dosimeter

Source of Uncertainties	Type A (%)	Type B (%)
Thimble Chamber of 0.6 cc (calibrated at BIPM) calibration factor		0.56
Scaling procedure		0.20
Conversion to absorbed dose to water		0.20
Source decay, half life		0.01
Dosimeter position in the Set-up		0.20
Irradiation temperature correction		0.15
Read-out dosimeter temperature correction		0.35
Reproducibility and repeatability	0.99	
Combined separately	0.99	0.76
Combined relative standard uncertainty	1.25	
Relative expanded uncertainty (95,45%)	2.50 %	

4.2 – Silver Dichromate and Potassium Dichromate (transfer Dosimeters)

4.2.1 – Silver Dichromate Dosimeter

A number of 125 dosimeters of silver dichromate have been irradiated with doses ranging between 1.0 - 8.3 kGy to build the calibration response curve.

$$D_{AgDic} = \frac{9.580.\Delta A}{[1+0.001(T-25)][1-0.002(T'-25)]} (Gy) \quad (2)$$

Where

- D_{AgDic} = Absorbed Dose (Gy)
- ΔA = Absorbance reduction at 350 nm
- T = read-out temperature
- T' = Irradiation temperature

4.2.2 – Potassium Dichromate Dosimeter

A number of 50 dosimeters of Potassium Dichromate have been irradiated with dose ranging between 3.0 - 49.0 kGy to build the calibration response curve.

$$D_{kDic} = \frac{60.083.\Delta A}{[1+0,001(T-25)][1-0,002(T'-25)]} (Gy) \quad (3)$$

Where

- D_{kDic} = Absorbed Dose (Gy)
- ΔA = Absorbance reduction at 440 nm.
- T = read-out temperature
- T' = Irradiation temperature

4.2.3 – Uncertainties of the transfer dosimeters

The same methodology to estimate uncertainties used in the reference dosimeter, was used to transfers dosimeters, and are shown in the table 2.

Table 2 – Uncertainties of the transfer dosimeters

Silver Dichromate Dosimeter	Type A (%)	Type B (%)
Combined separately	0.53	1.59
Combined relative standard uncertainty	1.68	
Relative expanded uncertainty (95,45%)	3.36 %	
Potassium Dichromate Dosimeter	Type A (%)	Type B (%)
Combined separately	1.67	1.59
Combined relative standard uncertainty	2.31	
Relative expanded uncertainty (95,45%)	4.62 %	

4.3 – Comparison between Silver Dichromate and PMMA routine dosimeter in the industrial irradiator

A set of dosimeters have been used to compare transfer dosimeter and routine dosimeters response in routine operation of the industrial irradiator. The results showed good agreements.

Table 3 – Comparison between Silver dichromate and PMMA

Irradiation position	Silver Dichromate Dose (Gy)	PMMA Dose (Gy)	Dicromato PMMA
A	1,822.6 ± 53.1	1,900 ± 95	0,959
B	2,916.6 ± 75.8	3,100 ± 155	0,941
C	4,895.7 ± 81.1	4,800 ± 240	1,020
D	6,753.5 ± 36.4	6,600 ± 330	1,023

5. CONCLUSION

The end results conclusions have demonstrated that studied dosimeters have shown a metrological quality for each respective class. Therefore, it can be stated that the applied methodology is valid to implement standard high-dose measurement LAB. It is important to point out that the quality presented by these dosimeters can be used to guarantee certification requirements and also to reduce irradiation facility dosimetry costs, by up to 20%, compared to current costs.

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