CALIBRATION OF ROUTINE DOSIMETERS IN RADIATION PROCESSING: VALIDATION PROCEDURE FOR IN-PLANT CALIBRATION

by

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The essential prerequisite of radiation dosimetry is to provide quality assurance and documentation that the irradiation procedure has been carried out according to the specification requirement of correct calibration of the chosen dosimetry system. At the Radiation Plant of the Vinča Institute of Nuclear Sciences we compared two recommended protocols of irradiation procedures in the calibration of dosimetry systems in radiation processing: (1) by irradiation of routine dosimeters (ethanol-chlorobenzene – ECB) at the calibration laboratory and (2), by in-plant calibration with alanine transfer – dosimeters. The critical point for in-plant calibration is irradiation geometry, so we carefully positioned the phantom carrying both dosimeters in order to minimize dose gradients across the sample. The analysis of results obtained showed that the difference among determined absorbed doses for the construction of calibration curves between these two methods, (alanine *vs*. ECB), is less than 1%. The difference in combined standard uncertainty for each calibration procedure is 0.1%. These results demonstrate that our in-plant calibration is as good as calibration by irradiation at the calibration laboratory and validates our placement of the irradiation phantom during irradiation.

Key words: radiation processing, cobalt-60, dosimetry, in-plant calibration

INTRODUCTION

Radiation processing requires the proper use and selection of a dosimetric system for the measurement of the absorbed dose in all areas. Quality control in radiation processing is essentially based on the validation of the calibration procedure and the assurance that the process was performed within prescribed dose limits. International guidelines for dosimeter calibration recognize two possible procedures [1]: (1) the calibration of a routine dosimetry system can be carried out directly in a national or accredited standard laboratory by standardized irradiation of routine dosimeters; (2) An alternative method requires routine dosimeters to be irradiated along with reference or transfer-standard dosimeters in the production irradiator (in-plant calibration). The first method is preferred by many, however, one NPL report [2] recommends calibration by irradiation in the plant where the dosimeters are to be used in the first place, because this procedure accurately reflects conditions under which actual irradiation occurs. This is the reason why, in recent times, in-plant calibration is in use more and more in radiation processing [3, 4]. Although it seems very satisfactory to exclude environmental effects in dose measurements, in-plant calibration can have one principal shortcoming when it comes to calibration by the first method: the irradiation geometry is not defined. The position of the calibration phantom within the product box undergoing irradiation has to be carefully selected and has to be validated.

The present paper evaluates both recommended methods and investigates their advantages and disadvantages under concrete irradiation conditions of gamma radiation processing at the Radiation Plant of the Vinča Institute where ethanol-chlorobenzene (ECB) dosimeters were used as routine dosimeters.

MATERIALS AND METHODS

The Radiation Unit of the Vinča Institute has been described in more detail elsewhere [5], thus only a brief description illustrative of the irradiation geom-

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etry will be given here. The source frame (1 m × 3 m) is loaded with 4.81 10^{15} Bq of ^{60}Co placed into source rods (diameter 11.1 mm, length 451 mm). Several generations of source rods are mixed in the said source frame. One automatic conveyer carries boxes (46 cm 46 cm 43 cm) through the source. A single irradiation run consists of four sequential irradiation cycles and in each cycle a given box passes through the irradiation room at one of four vertical levels organized in 6 rows (3 rows on each side of the source) with 12 horizontal positions in each one, *i. e*. every box is irradiated in the same way. The distances between boxes in neighboring rows, as well as between the source frame and the boxes in the rows next to them are small (a few cm), and the dose gradient, particularly in the rows nearest to the source, is large. Dose distribution was measured at a distance of 3 cm from the front of the source frame, using ECB dosimeters.

ECB dosimeters were prepared at the Vinča Institute in accordance with the procedures described in the corresponding standard [6] and placed in 2 ml glass, flame-sealed pharmaceutical ampoules. One batch (I) was calibrated by irradiation in well-defined conditions at the Riso High Dose Reference Laboratory (HDRL) [7]. The second batch (II) was prepared for in-plant calibration. The HDRL calibration phantom (fig. 1, see also [2]) with dosimeters consisting of: (1) three ampoules with an ECB solution (batch II), (2) two ECB ampoules from batch I, and (3) an alanine dosimeter, supplied by HDRL for in-plant calibration, were placed in the central part of the box with the product for sterilization. The phantom was positioned vertically and perpendicular to the incoming beam, so that all dosimeters were at the same depth and with no shielding of each other. The boxes were irradiated in sterilization cycles of 5 kGy to 35 kGy. The absorbed doses of the ECB dosimeters were measured by the OK–302/2 oscillotitrator [6], while the alanine dosimeters were sent to HDRL for dose determination.

Figure 1. HDRL iradiation phantom showing positions of alanine pellet and ECB ampoules

RESULTS AND DISCUSSION

In-plant calibration is critical in irradiation geometry. An erroneous positioning of the irradiation phantom during irradiation can be the source of error in determining the absorbed dose in calibration, so this position should be validated. Vertical dose distribution, just in front of the central part of the source plane, is presented in fig. 2. The dose distribution shows a small local minimum in the center of the source, because source rods are placed in the frame at two vertical levels and this position should be avoided during calibration. The nearest surface of the box is approx. 15 cm removed from the source, which decreases the potential dose gradient across the box; nevertheless, we positioned our calibration phantom facing the source in the central part of the box. In addition, entire irradiation runs were chosen for our in-plant calibration.

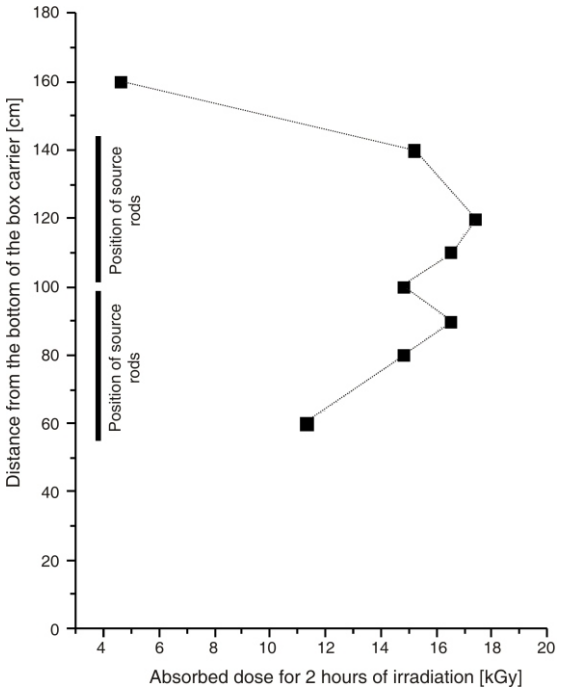

Figure 2. Vertical dose distribution at a distance of 3 cm from the central part of the source plane, as measured by ECB dosimeters

The results of the calibration procedure of routine dosimeters are presented in tab. 1. Absorbed doses from tab. 1 were used for designing the calibration dia-

Table 1. Absorbed doses of standard alanine dosimeters irradiated in Vinča Institute (in-plant) and measured in HDRL (first row) and ECB dosimeters (batch I) irradiated in HDRL and measured in Vinča Institute (second row)

Alanine dosimeters	6.2	0.02	12.7	0.1	23.8	0.38	34.5	0.3
ECB dosimeters	6.2	0.05	12.8	0.1	23.9	0.2	34.1	0.3

gram of the new batch (II) of ECB dosimeters (fig. 3). The differences in absorbed doses measured by standard alanine and ECB dosimeters are within 1%, which is an excellent agreement between the two methods. This is important since these two dosimeters have different geometries (thin alanine pellets of few mm *vs*. "bulky" ECB ampoules of 10.7 mm 0.2 mm) and the dose gradient across the calibration phantom can induce a difference in the dose delivered to the two dosimeters.

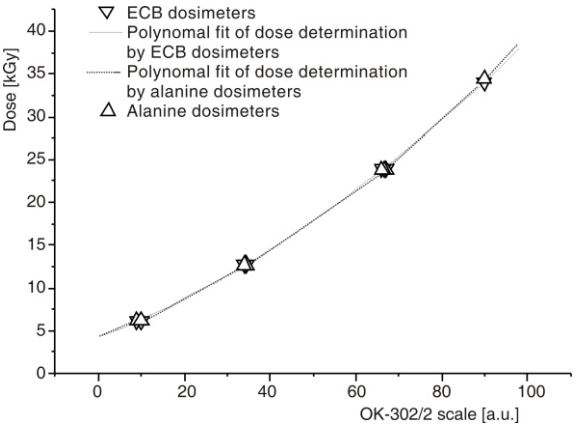

Figure 3. Calibration curves for the new batch of ECB dosimeters (routine dosimeters) for doses between 5 kGy and 35 kGy; oscillotitrator readings are compared to doses measured by two standard dosimeters (tab. 1)

According to international standards [2, 8], the test for the goodness of a fit for a calibration curve is a residual: the difference between the measured and predicted values. A lower value for the residual means a better fit. Figure 4 represents the residuals of calibration curves presented in fig. 3. As can be seen, the residuals of these two calibrations are also very similar. The highest value for residuals is 2% for doses below 10 kGy. Residuals decrease when the absorbed dose increases, which is to be expected since the relative error is smaller when the measured value increases. This goes to show that our in-plant calibration using alanine dosimeters appears to be as good as calibration by irradiation at the calibration laboratory.

For the comparison of two recommended methods of calibration, overall uncertainties were calculated according [2, 9, 10]. The uncertainties of the

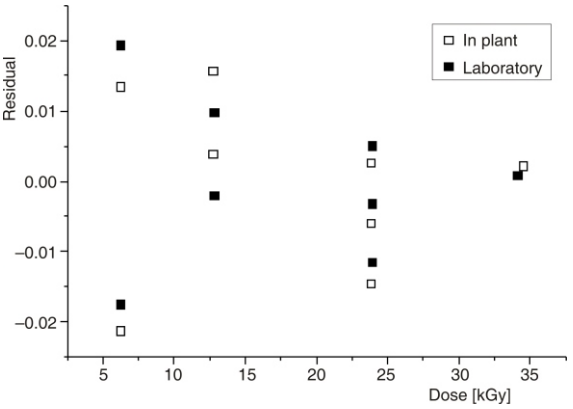

Figure 4. Residuals for curves presented in fig. 3

nominal dose for dosimeters irradiated in HDRL are: ECB ampoules, 3%; alanine, 2.6%. Under the conditions of this study, the difference between the two dosimeters is less than 1% (tab. 1). The effects of irradiation temperature on dosimeter readings should also be taken in consideration, since the readings of alanine dosimeters are temperature-sensitive, while those of the ECB dosimeters are not. Knowing the temperature range during irradiation (day/night variations) corresponding to the temperature dependence of dosimeter responses given in the standard [10], the estimated uncertainty is 1.3%. Hence, the combined standard uncertainty is 3.1% for in-plant calibration using alanine dosimeters.

In conclusion, both irradiation procedures of dosimeter calibration have the same level of uncertainty; hence, in-plant calibration is certainly the method of choice, providing a careful placement of the irradiation phantom was realized. The NPL report [2] recommends in-plant calibration verification when calibration is performed by irradiation in the calibration laboratory, but the verification is important in in-plant calibration as well, so as to validate the good placement of the irradiation phantom during irradiation.

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REFERENCES

[1] ***, ISO/ASTM 51261, Guide for Selection and Calibration of Dosimetry Systems for Radiation Processing, 2002
[2] Sharpe, P., Miller, A., Guidelines of Calibration of Dosimeters for Use in Radiation Processing, NPL Report CIRM 29, 1999
[3] Farah, K., *et al*., Characterization of a Silicate Glass as a High Dose Dosimeter, *Nucl Instrum Methods Phys Res A, 614* (2010), 1, pp. 137-144

[4] Fuochi, P. G., *et al*., In-Plant Calibration and Use of Power Transistors for Process Control of Gamma and Electron Beam Facilities, *Radiat Phys Chem*, *71* (2004), 1-2, pp. 385-388
[5] Marković, V. M., Eymery, R., Yuan, H. C., A New Approach to ^{60}Co Plant Design for Introduction of Sterilization in Developing Countries, *Radiat Phys Chem, 9* (1977), 4-6, pp. 625-631
[6] ***, ISO/ASTM 51538, 2002, Standard Practice for Use of the Ethanol-Chlorobenzene Dosimetry System
[7] 130.226.56.153/nuk/HDRL.htm
[8] ***, ISO/ASTM 51707, 2002, Standard Guide for Estimating Uncertainties in Dosimetry for Radiation Processing
[9] ***, Guide to Expression of Uncertainty in Measurements, International Organization for Standardization, Geneva, Switzerland, 1993
[10] ***, ISO/ASTM 51607, 2002, Practice for Use of Alanine – EPR Dosimetry System

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КАЛИБРАЦИЈА РУТИНСКОГ ДОЗИМЕТРА У ТЕХНОЛОГИЈИ ОБРАДЕ ОЗРАЧИВАЊЕМ: ПРОЦЕДУРА ВАЛИДАЦИЈЕ ЗА КАЛИБРАЦИЈУ У ТОКУ ОБРАДЕ ОЗРАЧИВАЊЕМ

Основни циљ радијационе дозиметрије је да обезбеди контролу квалитета и документује да се процес озрачивања одвијао према захтевима добре праксе калибрације изабраног дозиметријског система. У Радијационој јединици Института за нуклеарне науке „Винча” поредили смо два препоручена протокола озрачивања дозиметра приликом њихове калибрације када се користе у технологији обраде озрачивањем: (1) озрачивањем рутинских дозиметара (етанол-хлорбензен) у референтној лабораторији и (2) калибрацијом у току технолошке обраде озрачивањем коришћењем аланинских дозиметара као трансфер дозиметара. Геометрија озрачивања је критична тачка калибрације у току технолошке обраде озрачивањем, због чега смо пажљиво изабрали место фантома у коме се налазе обе врсте дозиметара тако да је градијент дозе минималан кроз фантом. Анализа резултата је показала да је разлика у одређивању апсорбованих доза које су се користиле у конструкцији калибрационих кривих (аланин према хлорбензену) мања од 1%. Разлика између комбинованих стандардних неодређености између ових калибрационих процедура је 0,1%. Ови резултати показују да је наша калибрација у току технолошке обраде озрачивањем једнако добра као и калибрација озрачивањем у референтној лабораторији и валидира наш избор места за фантом током озрачивања.

Кључне речи: обрада озрачивањем, кобалт-60, дозиметрија, калибрација у радијационој јединици