INTERCOMPARISON OF SPANISH ENVIRONMENTAL DOSIMETRY SERVICES AT $^{137}$Cs ENERGY

*1C. García Mulas, 1A. M. González Leitón, 1A. Brosed, 1J. M. Los Arcos, 2R. Salas, 2I. Marugán, 2Lucila Mª Ramos.

1Laboratorio de Metrología de Radiaciones Ionizantes. CIEMAT. Madrid. Spain.
2Área de Vigilancia Radiológica Ambiental. CSN. Madrid. Spain.

Abstract. According to its annual plan for inter-comparison exercises, the Spanish regulatory body (Nuclear Safety Council, CSN) organized in 2007, in collaboration with CIEMAT, the third national inter-laboratory comparison test among the services of environmental dosimetry in Spain.

The radiological quantity used was the ambient dose equivalent, $H(10)$. Different values of this quantity were assigned to each laboratory. These values ranged between 210 and 390 $\mu$Sv. All dosimeters were exposed at the same air kerma rate level and practically at the same distance from the source. $H(10)$ was estimated following the procedures for area and portable meters described by the International Organization for Standardization (ISO) in the ISO 4037-3 document [1].

Conventionally, an environmental dosimeter calibrated in units of ambient dose equivalent is used to estimate the limiting quantities of ICRP. However, this is at the end the same objective than that of a personal dosimeter. Therefore, we can use the same evaluation procedure for both the environmental and the personal dosimeters. The analysis of results was carried out following two procedures: firstly, by comparison with the criteria established in the new ANSI 13.11 standard (2001 version) [2] and second, by analysis of the “trumpet curves” [3].

This paper presents the results obtained by the seven laboratories (two of them contributing with two different dosimetry systems) included in the study, which participated on a voluntary basis, all of them using different thermoluminiscent detectors and dosimetric units. All results are in full agreement with the evaluation procedures, lying within the tolerance limits fixed by the trumpet curves [3] and satisfying the Q<0.4 requirement established by the mentioned ANSI 13.11-2001 standard [2].

KEYWORDS: Environmental dosimetry, $^{137}$Cs, comparison

1. Introduction

The Nuclear Safety Council organized in 2007, in collaboration with CIEMAT, a national inter-laboratory comparison exercise among the services of environmental dosimetry in Spain. The goal of the comparison was to verify the traceability level of the dosimeter-reader units with respect to the national gamma dosimetry standard at the $^{137}$Cs energy. This intercomparison is a very useful tool in order to assess the quality assurance of the laboratories and allows the application of corrective actions if it were necessary.

This paper presents the results obtained by the nine dosimetry systems used by the seven laboratories included in the study, which participated on a voluntary basis.

2. Material and methods

All irradiations were carried out at the Ionising Radiations Metrology Laboratory (LMRI) of the Center for Energy, Environment and Technology Research (CIEMAT), in Madrid, Spain, following internal procedures included in its ISO17025 quality management system and using a $^{137}$Cs source of 1.5 TBq nominal activity (october, 1983).

A point source assumption was made on the basis of measurements of photon fluence uniformity and beam alignment in the calibration plane. The dosimeters were mounted on a nylon fiber net which was
set up perpendicular to the beam axis at the calibration plane where the photon fluence is uniform and the reference air kerma rate is well known. The distance from the dosimeters net at the calibration plane and the source reference plane was 3.6 m, with the source emission collimated to a circular beam diameter of about 51 cm.

Seven services of environmental dosimetry participated in the comparison, two of them contributing each with two different dosimetric systems. All participants used thermoluminiscent detectors. The nine dosimetric systems were labelled, 1, 2, 3a, 3b, 4, 5, 6a, 6b and 9.

Each dosimetry service supplied a set of 25 dosimeters for each dosimetric unit to be tested. Within each set, 10 dosimeters were to be irradiated, 10 other dosimeters were included to measure the transit dose, and the remaining 5 dosimeters were included as reserve in order to repeat irradiations that could be necessary. No more than four dosimeters were exposed at a time.

All dosimeters were exposed at the same air kerma rate level and practically at the same distance from the source. The radiological quantity used was the ambient dose equivalent, \( H^{*}(10) \). \( H^{*}(10) \) was estimated following the procedures for area and portable meters described by the International Organization for Standardization (ISO) in the ISO 4037-3:1999 document [1].

The 10 dosimeters irradiated in each dosimetric system received the same value of ambient dose equivalent, and different values of this quantity, ranging between 210 and 390 \( \mu \)Sv (0.3 mSv \( \pm \) 30%), were assigned at random to each dosimetric system following a logarithmic algorithm similar to that proposed in the ANSI 13.11-2001 standard [2].

3. Results

Conventionally, an environmental dosimeter calibrated in units of ambient dose equivalent is used to estimate the limiting quantities of ICRP. However, this is at the end, the same objective than that of a personal dosimeter. Therefore, we may use the same evaluation procedure for both the environmental and the personal dosimeters. The analysis of results was carried out following two procedures: firstly, by comparison with the criteria established in the new ANSI 13.11 standard (2001 version) [2] and secondly, by analysis of the “trumpet curves”[3].

3.1 Criteria according to ANSI 13.11-2001 standard [2]

The ANSI 13.11-2001 defines the following parameter:

**Performance quotient (\( P_i \)):** The performance quotient for the \( i^{th} \) dosimeter is defined as:

\[
P_i = \frac{(M_i - M_v)}{M_v}
\]

where \( M \) is the dose equivalent determined in that dosimeter by the participating laboratory and \( M_v \) is the conventional true dose equivalent (for the batch).

**Performance Testing Bias (B):** The bias of the values of the performance quotient, \( P_i \), is set equal to the average of these values:

\[
B = \frac{1}{n} \sum_{i=1}^{n} P_i
\]

where the sum is extended over all \( n \) values of \( P_i \).

**Standard deviation (S):** The Standard deviation of the values of the performance quotient, \( P_i \), is:

\[
S = \sqrt{\frac{\sum_{i=1}^{n} (B - P_i)^2}{n - 1}}
\]
where the sum is extended over all \( n \) values of \( P_i \).

**Performance Criterion (Q):** Performance in a given category shall be considered adequate if:

\[
Q = |B| + S = L
\]

where \( L \) is the tolerance level = 0.4.

Figure 1 shows the \( Q, B \) and \( S \) values obtained for the nine dosimetric systems. \( Q \) values are given the sign of \( B \) values in order to check whether \( H^*(10) \) values are underestimated or overestimated.

**Figure 1:** Evaluation of the results according the ANSI 13:11 standard.

Table 1 shows the distribution of dosimetric systems for different ranges of \( B, S \) and \( Q \) values.

**TABLE 1.** Distribution of dosimetric systems for different ranges of \( B, S \) and \( Q \) values

<table>
<thead>
<tr>
<th>TOLERANCE</th>
<th>ACCEPTED DOSIMETRIC SYSTEMS</th>
<th>FRACTION (%)</th>
<th>ACCEPTED DOSIMETRIC SYSTEMS</th>
<th>FRACTION (%)</th>
<th>ACCEPTED DOSIMETRIC SYSTEMS</th>
<th>FRACTION (%)</th>
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<td>11</td>
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<td></td>
<td>9</td>
<td>100</td>
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</tbody>
</table>
3.2 Criteria according to trumpet curves [3]

According to ICRP 60 [4], the tolerance on the estimation of dose around the recording level will be a factor of 2, and of 1.5 around the dose limit. Between both levels, the results were analysed following the so-called trumpet curve criteria:

Upper Level:
\[
\left( \frac{H_m}{H_v} \right)_{UL} = 1.5 \left( 1 + \frac{H_0}{2H_0 + H_v} \right)
\]

Lower Level:
\[
\left( \frac{H_m}{H_v} \right)_{LL} = \frac{1}{1.5} \left( 1 - \frac{2 \cdot H_0}{H_0 + H_v} \right)
\]

where \( H_m \) is the dose equivalent assigned by the participating laboratory to the irradiated dosimeter and \( H_v \) is the conventional true dose equivalent. \( H_0 \) is the lowest dose required to be measured. (\( H_0 = 0.1 \) mSv in Spain).

Figure 2 shows the \( H_m/H_v \) values obtained for the individual dosimeters. A different colour is assigned to each dosimetric system.

Figure 2: Evaluation of the results according the trumpet curves.

4. Conclusion

The reference values, i.e. the \( H^*(10) \) values imparted by the pilot laboratory to the dosimeters of the participating laboratories, were in the range about 232-390 µSv. The corresponding raw readings had to be corrected for the “accumulated transit dose” which was between 6%-18%, with an “accumulated transit dose per day” between 2-5 µSv.
All dosimeters from the nine dosimetric systems fully satisfy both evaluation criteria. All of them are within the tolerance limits defined by the “trumpet curves” and all the dosimetric units fulfil the Q ≤ 0.4 tolerance limit defined by the ANSI 13.11-2001 standard.

Table 1 shows that the set of nine dosimetric systems has a Q-value < 0.3 and a subset of 6 units has a Q-value ≤ 0.1. Besides, the repeatability of measurements is good enough since the set of nine systems presents an S-value ≤ 0.06.

With regard to the eventual mismatch of the dosimetric systems for the $^{137}\text{Cs}$ energy, the situation is also good, since 8 laboratories show a value $|\beta| \leq 0.10$, an exception being the laboratory no. 2 with a B-value =0.237. Also the repeatability of measurements has been satisfactory, since all laboratories present S-values < 0.10.

Finally, concerning the evaluation of results by the trumpet curves, the analysis of Figure 2 shows that all the points in the nine dosimetric units fully satisfy the evaluation criteria.

5.- References


6.- Acknowledgments

We acknowledge the voluntary participation and collaboration of all seven environmental dosimetry services that kindly took part in this inter-comparison exercise.