EURADOS INTERCOMPARISONS FOR INDIVIDUAL MONITORING SERVICES: RESULTS AND CONCLUSIONS FROM THE FIRST THREE EXERCISES

Stadtmann H.[1], Grimbergen T.W.M. [2] , McWhan A.[3*] Figel M.[4], Romero A. M.[5]

[1] Radiation Safety and Applications, Dosimetry Head, Seibersdorf Labor GmbH, 2444 Seibersdorf, Austria
[2] Radiation and Environment Group, NRG, PO Box 9034, 6800ES, Arnhem, Netherlands
[3*] Berkeley Approved Dosimetry Service, Babcock International Group, A11 Berkeley Centre, Berkeley, Gloucestershire, GL13 9FB, United Kingdom
[4] Auswertungsstelle (Personal Monitoring Service) Helmholtz-Zentrum Muenchen, Otto-Hahn-Ring 6, D-81739, München, Germany
[5] Radiation Dosimetry Service, CIEMAT, Avda Complutense, 40, 28040-Madrid, Spain

ABSTRACT

In 2008 EURADOS (European Radiation Dosimetry Group) started a self sustaining programme of regular intercomparison exercises for individual monitoring services (IMS) in Europe. With the intercomparison results, each IMS can test the performance of their systems, compare their results with those from other participants and show compliance with the requirements set by regulatory or accreditation bodies. Thus, EURADOS provides a necessary service for all European dosimetry services and contributes to the harmonisation of personal dosimetry in Europe. In this paper the intercomparison programme organized by EURADOS is presented together with the details, results and conclusions of the intercomparisons held to date: IC2008 and IC2010 for whole body dosemeters and IC2009 for extremity dosemeters.

Key Words: Intercomparison, individual monitoring, dosemeter.

1. Introduction.

Personal dosimetry intercomparisons are considered an essential tool for the harmonisation of personal dosimetry services (also known as individual monitoring services –IMS) in Europe. Participation is specifically recommended in the new "Technical Recommendations for Monitoring Individual Workers Exposed to External Radiation" [1] and in the section on method validation in ISO/IEC-17025 [2], "General requirements for the competence of testing and calibration laboratories". However, up until now only a few European Union countries have been organising intercomparisons for personal dosimetry and, in general, these have been limited to IMS within the organising country.

EURADOS (European Radiation Dosimetry Group, www.eurados.org) is a non profit association that brings together over 200 scientists from over 50 institutions in the European Union, Switzerland and countries of Central and Eastern Europe and whose objective is to promote research, development and European co-operation in the field of dosimetry of ionizing radiation.

Recognizing the demand for intercomparisons and drawing on the structure of the large network of its members and the experience gained in organising previous intercomparisons, EURADOS decided to investigate the possibility of establishing a sustainable program of intercomparisons organised periodically, to be financed by fees paid by participants. Thus, EURADOS would contribute to the knowledge of the current state of dosimetry in Europe and the harmonisation between the different

IMS. This study was commissioned by the working group EURADOS 2 (WG2) for the "Harmonisation of personal dosimetry in Europe", presented at the 2007 EURADOS Annual Meeting. The frequency was set at the rate of one intercomparison per year, with whole body dosemeter intercomparison held every second year with extremity or neutron dosemeter intercomparisons held on alternate years.

The intercomparison program was established taking into account the requirements of ISO-14146 [3] in terms of qualities and angles of irradiation, the dose range, the number of dosemeters irradiated and background, etc. The choice of laboratory irradiation was limited to accredited reference laboratories in order that the intercomparsion results would be useful for IMS which have ISO/IEC-17025 accreditation [2]. However, since EURADOS is not approved for the evaluation of IMS, ie for the purposes ISO-14146 [3], it was decided that the results of the intercomparison would be presented to the participants as a "Certificate of Participation", accompanied by a certificate issued by the accredited laboratory irradiation. The “Certificate of Participation” does not make any assessment of the results because the specified national criteria differ from country to country.

2. Intercomparison Phases

The Council appoints a group EURADOS organiser (OG) for each intercomparison, one of whom acts as co-ordinator. The OG decides the scope of each campaign, defines the irradiation plan, hires the laboratory irradiation intercomparisons, analyses the results of the participants, prepares individual certificates of participation and prepares the final report. Each intercomparison can be considered as four phases: 1) preparation, 2) announcement and registration, 3) execution and 4) reporting.

In the preparation phase, the OG develops a proposal for intercomparison in defining the scope, establishing the irradiation plan (radiation qualities and dose range) and sets the budget and provisional timetable. The OG then contacts suitably accredited calibration laboratories for quotes, based on an outline of the proposed irradiation and the number of expected participants. As EURADOS is a non-profit making organisation, the fee is based on the total costs and the minimum number of participants to balance income and expenditure. When the quotes have been received and the budget has been finalised, the OG presents the proposal to the EURADOS Council for formal approval.

Once the proposal has been approved, the second phase starts with the formal announcement of the intercomparison on the EURADOS website with a copy sent by email to all IMS on the OG mailing list. The announcement includes information about the type of intercomparison, the dose ranges, energies and angles of irradiation and the schedule for the year. Those interested in participating must complete an application form (which includes terms and conditions). The application form can be downloaded from the EURADOS website. If the minimum number of participants (set by the budget) has been reached, the selected irradiation laboratory is formally notified.

The third phase begins with participants sending confirmation of participation. Instructions for sending dosemeters and the corresponding invoice are then sent back to the selected participants. Participants must label their dosemeters and send these to the co-ordinator. The coordinator receives all the dosemeters and attaches new labels with an organisation code. The dosemeters are sent to an irradiation laboratory (or laboratories). Each shipment is accompanied by an electronic dosemeter to monitor the doses received in transit. When the irradiated dosemeters are returned to the co-ordinator, the new OG labels are removed and the dosemeters are returned to the IMS participant dosemeters for evaluation along with instructions for sending results.

After receiving the results, the co-ordinator calculates the value of the response, R, for each dosemeter by dividing the participant's result, H_p, participant, by the reference dose given laboratory H_p, reference, according with equation (1).

$$R = \frac{H_{p,participant}}{H_{p,reference}} \quad (1)$$

The calculated response values are sent to each participant for the initial check and confirmation (with the opportunity to comment). Thus, each participant is informed of the radiation qualities and the doses given to their dosemeters. Any comments received after that time are discussed by the OG to decide if any applications for result modification can be permitted. As a general rule, the OG only accepts changes to the results when it is proven that there has been an error by the OG or by the irradiation laboratory.

In the last phase, the coordinator prepares the "Certificates of Participation" which are signed by the coordinator and the president of EURADOS. These certificates are issued to participants at the "Participants' Meeting" which OG holds at the end of each intercomparisons.

Finally, the OG prepares and sends a questionnaire to participants to gauge the value of the intercomparison, the need for new intercomparisons and areas for improvement. All data is treated as strictly confidential and the IMS identification code used for analysing results is known only to participants and the coordinator. In addition, the irradiation laboratory carries out the irradiations to each dosemeter to a dose value, randomly generated, close to the value proposed in the OG irradiation plan. This means that each participant's dosemeters receive slightly different dose values.

The details of organisation, execution and analysis of results for each intercomparison are presented in a Final Report which is prepared by the OG when each intercomparison has been completed. For the analysis of results required for preparation of reports, the OG uses the "trumpet curve" method set out in ISO-14146 [3], for which the tolerance limits are given by equation (2) wherein F = 1.5 and H_0 is lower range of doses.

$$\frac{1}{F}\left(1-\frac{2H_0}{H_0+H_{p,ref}}\right) \le R \le F\left(1+\frac{H_0}{2H_0+H_{p,ref}}\right) \quad (2)$$

Following this methodology, three intercomparisons have now been completed: two in 2008 and 2010 for whole body dosemeters, and one in 2009 for extremity dosemeters. IC2012 for whole body dosemeters is now under way. A technical overview of the three completed intercomparisons is presented below.

3. EURADOS 2008 Intercomparison for whole body dosemeters (IC2008)[4]

Organising Group: T. Grimbergen, M. Figel, A. M. Romero, H. Stadtmann and A. McWhan, Co-ordinator: T. Grimbergen

Participants submitted 26 dosemeters of which 20 were irradiated with the photon qualities and values of Hp (10) and Hp (0.07) shown in Table 1. The remaining 6 dosemeters were used as spares and background dosemeters. The irradiation plan had been established to enable participants to obtain information about the performance of their systems with respect to linearity, reproducibility, energy dependence and angular measurement capability in mixed fields. These irradiations were performed in the Calibration Laboratory of Greek Atomic Energy Commission (GAEC) in Greece

A total of 52 IMSs from 24 countries participated with a total of 62 different dosimetric systems: 10 photographic film (Film), 46 thermoluminescence dosemeters (TLD) and 6 other techniques (Other) including optically stimulated luminescence (OSL), radiophotoluminiscence (RPL) and active personal dosemeters (APD). Of the 62 participants, 48 submitted results for both quantities and the remainder just submitted results for Hp (10).

Table 1: Irradiation Plan for IC2008

Quality	$H_p(10)$, $H_p(0,07)$ (mSv)	Number of dosemeters
N-60	3	2
N-60 45°	3	2
N-150 45°	3	2
N-60 + S-Cs	(3 + 1)	2
S-Cs + N-60	(3 + 1)	2
S-Cs	0.5	2
S-Cs	3	4
S-Cs	10	2
S-Co	150	2

Figure 1 shows the overall results of all participants as a function of the dose quantities Hp (10) and Hp (0.07) together with the representation of the trumpet curve. Most of the results (93% and 88%, respectively) are within acceptable limits; film dosemeters showed the largest deviations.

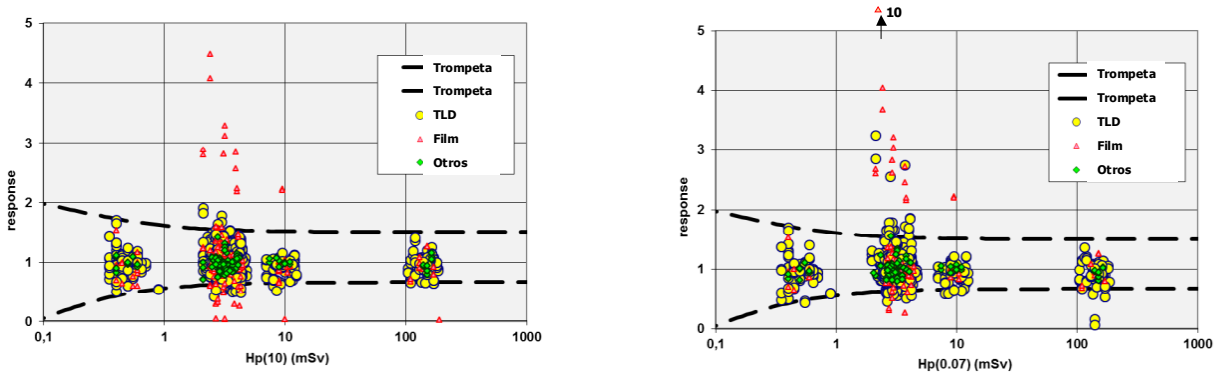

Figure 1: IC2008 results in terms of the dose delivered represented together with the trumpet curves (H_0 = 0.085 mSv)

Analysis of the results depending on the quality of radiation, as shown in Figure 2, shows that the median is at a value very close to unity in all cases, which means that the calibration procedures and in particular, traceability to national reference laboratories, are performing as expected. However, the N60 qualities (0 ° and 45 °) show the greatest spread of results: 15% of the response values fall outside the trumpet curve.

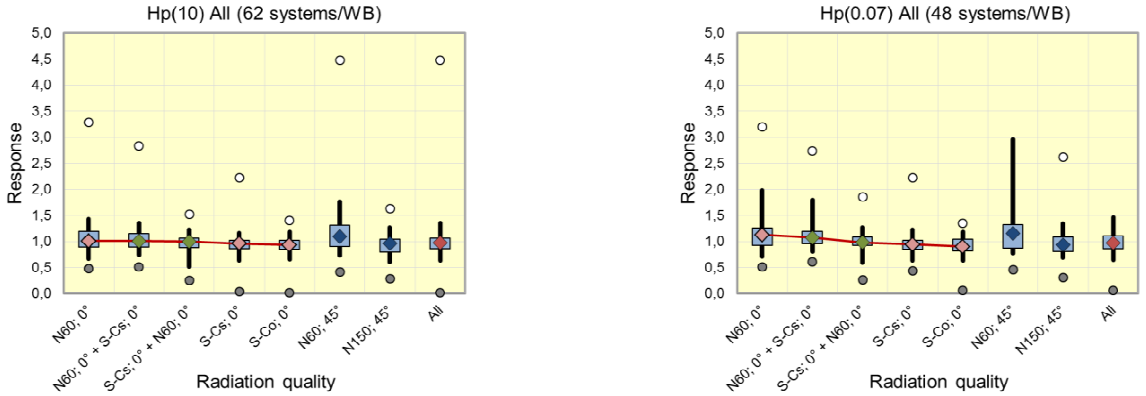

Figure 2: Results of the IC2008 depending on the quality of radiation. The values shown are the median (◊), percentiles 25% to 75% (bar), the percentiles 5% to 95% (vertical line), maximum (○) and minimum (●).

When the individual results of Hp (10) are presented for all participating systems based on the anonymous system identification number(Figure 3) it can be observed that most of the values outside the range 1/1, 5 ≤ R ≤ 1.5 come from photographic film dosemeters, although it is noted that some of them showed a good performance, comparable to that of the TLDs. TLDs based systems showed satisfactory results in general (96% of results within the trumpet curves) and the other systems presented only 1% of outliers.

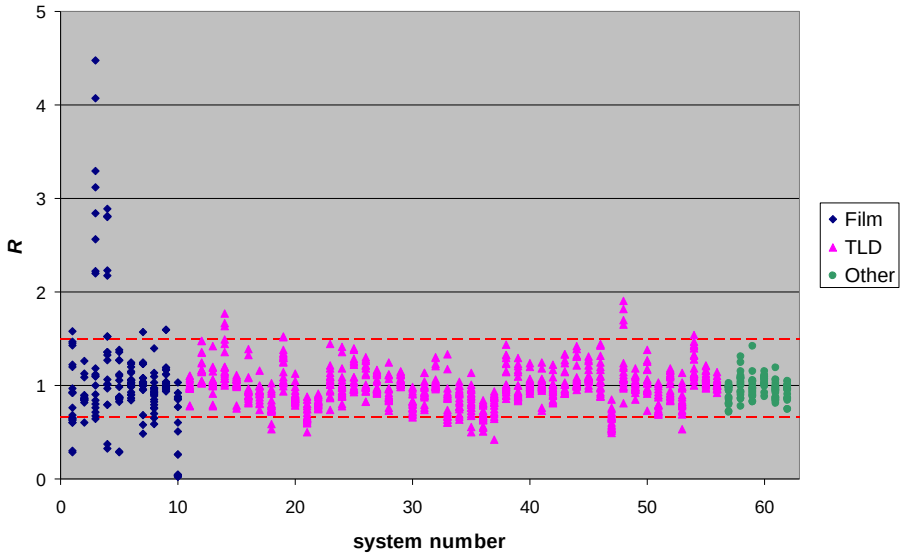

Figure 3: Individual results for Hp(10) for all participant systems in IC2008

4. EURADOS Intercomparison 2009 for extremity dosemeters (IC2009)[5]

Organising Group: T. Grimbergen, M. Figel, A. M. Romero, H. Stadtmann and A. McWhan
Coordinator: T. Grimbergen

For IC2009, each participant sent 28 extremity dosemeters of which 22 were irradiated with the photon qualities and beta energies for Hp (0.07) listed in Table 2. The remaining 6 dosemeters were used as spare and background dosemeters. The irradiation plan was designed to enable participants to obtain information on their systems with respect to linearity, reproducibility, energy dependence and angular qualities for their beta and photon responses. The irradiations were performed in calibration facilities in Seibersdorf in Austria and the Institut de Radioprotection et de Sûreté Nucléaire (IRSN) in France.

There were a total of 44 IMSs from 18 different countries with 59 dosemeter systems: 46 ring systems, 4 fingertip and 9 wrist / ankle dosemeters. Participants could choose to participate only with photons or beta radiation, or both. 21 IMS chose qualities systems involving photon, 37 chose photon and beta and one chose beta only. All participants used TLDs except for one participant who sent RPL glass dosemeters.

Table 2: Irradiation plan for IC2009

Radiation	Quality	Abreviation	Energy max beta / media photon keV	$H_p(0.07)$ mSv	Number of dosemeters
Beta	^{85}Kr; 0°	(Kr)	687	25	2
	^{90}Sr/^{90}Y; 0°	(Sr)	2274	10	2
	^{90}Sr/^{90}Y; 60°	(Sr60°)	2274	10	2
Photons	N-20; 0°	(N20)	16	40	2
	W-80; 0°	(W80L)	57	5	2
		(W80M)	57	50	4
		(W80H)	57	400	2
	W-80; 60°	(W80M60°)	57	50	2
	N-150; 0°	(N150)	118	25	2
	S-Cs; 0°	(Cs)	662	30	2

Figure 4 shows the overall results for all participants based on the value of Hp (0.07) given together with the trumpet curves. About 15% of the results are outside the trumpet curve; the dosemeters irradiated with beta radiation presented the highest deviations.

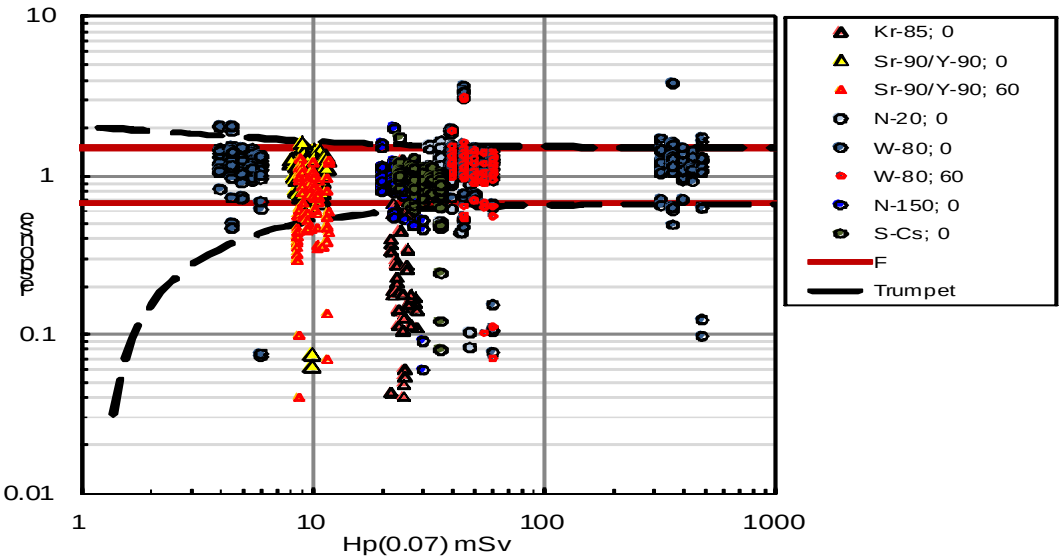

Figure 4: Results for IC2009 as a function of the dose represented together with the trumpet curves (H_0=1,25 mSv)

Figure 5 shows the results as a function of the quality of radiation. It must be noted that all the minimum and maximum values for all of the irradiations with photons are for just two dosimetry systems that consistently showed values too high or too low. As expected, the response values were lowest for the lower-energy beta (^{85}Kr; 0°) and wider angles (^{90}Sr/^{90}Y; 60°). Both the mean values of beta irradiation ^{90}Sr/^{90}Y;0 º and irradiation with photons remain close to unity.

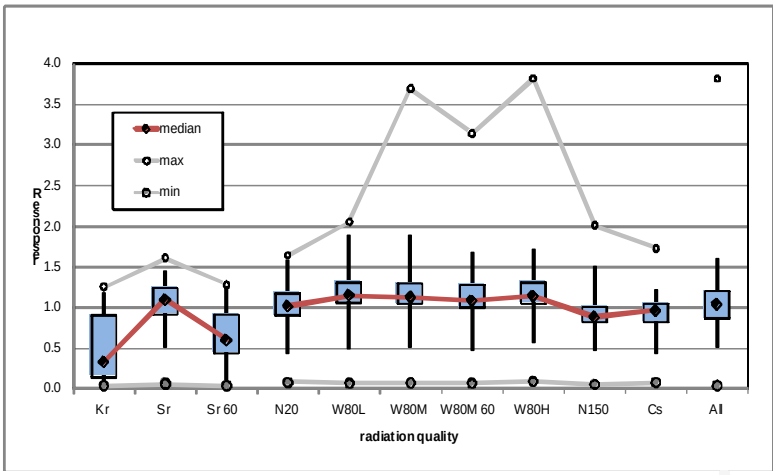

Figure 5: Results for IC2009 as a function of the radiation quality. The values shown are the median (◊), percentiles 25% to 75% (bar), the percentiles 5% to 95% (vertical line), maximum (○) and minimum (●).

If the individual results of Hp (0.07) are presented for all participating systems based on the number of anonymous system (Figure 6) it can be observed that most of the values outside the range 1/1, 5 ≤ R ≤ 1,5 correspond to the ^{85}Kr;0º and ^{90}Sr/^{90}Y;60° beta irradiations qualities. 71% of the systems designed for only photons passed the trumpet curve criteria while only 40% of those designed to measure photons and beta radiation met the criteria trumpet curve criteria in both capacities. The

dosemeter designed for beta only was within the trumpet curve. In total, only 31 of the 59 participating systems (52%) met the criteria of the trumpet curves.

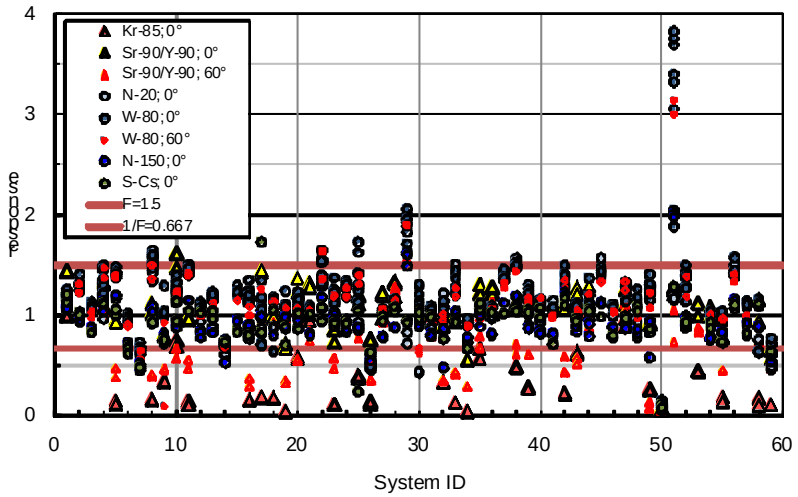

Figure 6: Individual results of Hp (0.07) for all systems participating in the IC2009.

5. EURADOS Intercomparison 2010 for whole body dosemeters (IC2010)

Organising Group: A. McWhan , E. Fantuzzi, M. Figel, T. Grimbergen , A. M. Romero and H. Stadtmann
Co-ordinator: A. McWhan

For IC2010, 26 whole body dosemeters were sent by each participant of which 20 were irradiated following the irradiation plan shown in Table 3. The remaining 6 were used as spare and background dosemeters. The irradiations were performed in the Calibration Laboratory BEV in Austria.

A total of 70 IMSs, from 30 countries participated with a total of 85 different dosimetric systems: 13 film, 59 TLD, 8 OSL and 5 based on other techniques (Other), ie radiophotoluminescence (RPL), direct ion storage (DIS) or active personal dosemeters (APD). Of the 85 participants, 66 submitted results for both quantities and the remaining 19 participated only in the magnitude Hp (10).

Table 3: Irradiation Plan for IC2010

Quality	$H_p(10)$, $H_p(0,07)$ (mSv)	Number of Dosemeters
N-40 30º	1	2
N-40 + S-Cs	3	2
W-110 45° X	5	2
W-110 45° Y	5	2
W-250 + S-Cs	3	2
S-Cs	0.5	2
S-Cs	2.5	4
S-Cs	12	2
S-Co	250	2

Figure 7 shows the overall results of all participants as a function of the dose given in the quantities Hp (10) and Hp (0.07) together with the representation of trumpet curves. In this exercise, the increase in OSL-based systems allowed the OG to study their behaviour as a new category of system. It can be seen that most of the results (95% and 91%, respectively) are within acceptable limits. Some TLD systems have shown greater deviations than in the IC2008 while film performance has improved.

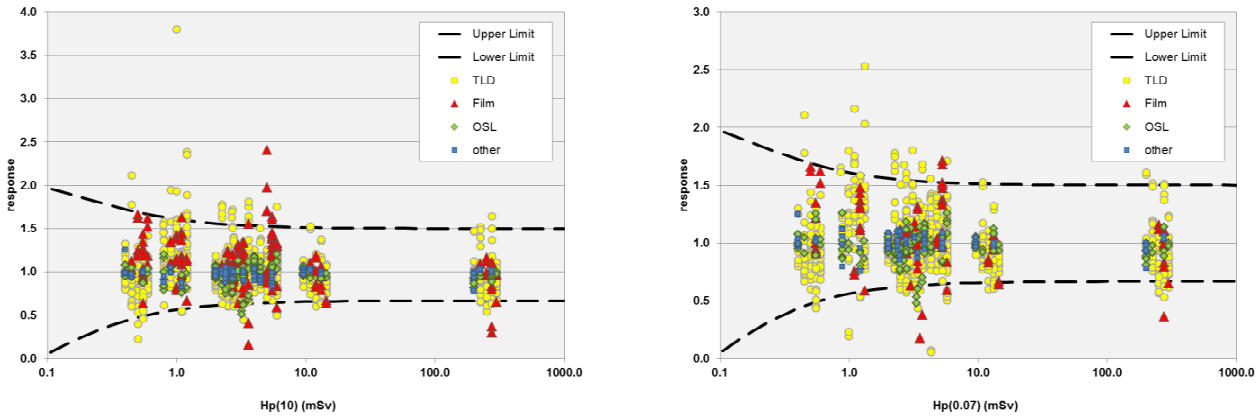

Figure 7: Results for IC2010 as a function of the imparted dose represented together with the trumpet curves (H_0=0.085 mSv).

If we analyze the results depending on the quality of radiation, as shown in Figure 8, the median is observed at a value very close to unity in all cases but there was a greater spread of results for N-40;30º quality which is due mainly to the behaviour of TLDs which had 10% of results outside the trumpet curve for this quality.

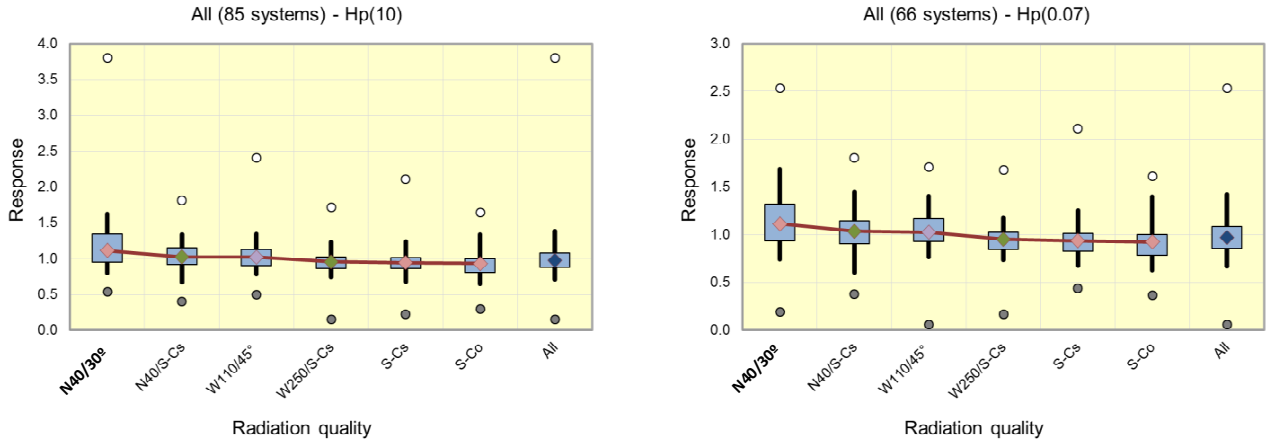

Figure 8: Results for IC2010 as a function of the radiation quality. The values shown are the median (◊), percentiles 25% to 75% (bar), the percentiles 5% to 95% (vertical line), maximum (o) and minimum (●).

Analysis of individual results show that 74% and 67% of the systems had results within the trumpet curves for the quantities Hp (10) and Hp (0.07), respectively. TLDs systems showed stable and satisfactory results in general, 76% of systems without outliers, yielding the poorest results for the

quality N-40/30º. Film-based systems were significantly improved with results down from 25% outliers in the IC2008 to 8% in IC2009. OSL dosemeters performed well with outliers only for N40/S-Cs quality. Note that the "Other" systems had all values within the trumpet curves for all qualities tested.

6. Conclusions

The programme of EURADOS intercomparisons has met the objectives for which it was established. Three self financed intercomparisons have now been completed and these indicate the contribution of the IC programme to the harmonisation of European IMS. The high number of participants confirms the interest and the need for IMS to participate in international intercomparison exercises to demonstrate the competence of their services. The results show a good performance in general, although it can be seen that there is some scope for improvement, in particular for extremity dosimetry. The OG is currently working on IC2012 for whole body dosemeters in photon fields and EURADOS is also organising an intercomparison specifically for neutron dosemeters in 2012.

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