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Braunschweig, June 2015

Quality Assurance in Individual Monitoring for External Radiation – Results of EURADOS Survey 2012

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P. J. Gilvin[1] , J.G. Alves[2], C. Cherestes[3], J.W.E. van Dijk[4], M. Lehtinen[5], F. Rossi[6], B. Vekic[7] and M-A Chevallier[8].

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Content:

Abstract

EURADOS Working Group 2 (WG2) on Harmonization of Individual Monitoring is a network of institutions and individual monitoring services (IMSs), built up over the last 20 years, that aims to promote quality, technical excellence and good practice in Europe. In pursuit of these aims, in 2012 WG2 carried out a survey of IMSs in Europe. The survey was sent to about 170 IMS and included questions on: the use of formal quality assurance (QA) standards, QA in dosimetry, matters of practice, and common sources of error. This report details the main findings of the survey and compares them with those of an earlier study (2003). The survey found that the profile of QA is high amongst the responding IMSs, and that most are following good practice. A majority of services comply with published quality standards and good attention is paid to traceability, validation of methods, and proficiency testing. However there are some areas where lessons can be learned, for example in the assessment of measurement uncertainty; and it remains very instructive to see what the main causes of error are for IMSs in general.

1. Introduction

1.1 Background: EURADOS Working Group 2

In the field of individual monitoring for occupational exposure, the reliability and quality of individual monitoring services (IMS) are of the utmost importance. EURADOS Working Group 2 (WG2) on Harmonization of Individual Monitoring has set up a network of institutions and individual monitoring services (IMSs). WG2 aims to promote quality, technical excellence and good practice in European Member States. EURADOS started this action in 1997, with financial support of the European Commission (EC), setting up an action group to look at the degree of harmonisation of the dosimetric requirements and procedures for individual monitoring in European Union (EU) Member States. The main reason for this initiative was the publication of the Council Directive 96/29 EURATOM of 13 May 1996 'laying down basic safety standards for the protection of the health of workers and the general public against dangers arising from ionizing radiation'[1]which would need to be met by Member States from 13th May 2000. The aims included:

- evaluating the implementation in individual monitoring practice of the then new operational quantities Hp(0.07) and Hp(10)
- consolidating within the EU the quality of individual monitoring using personal dosemeters
- assisting movement towards harmonised procedures
- evaluating the performance of individual dosemeters in photon, beta and neutron fields [2].

These topics motivated further work by WG2 taking into consideration the enlargement of EU [3]. WG2 also collaborated in the organization of the individual monitoring conferences IM2000 [4], IM2005 [5] and IM2010 [6] that largely contributed to the dissemination of the findings. The implementation of quality assurance standards and measurement quality standards for individual monitoring of external radiation has since been one of the focal topics. WG2 has continued to meet its goals with the publication of revised technical recommendations known as "RP160" [7], by the European Commission as a result of the EU-TRIMER project funded by EC. Moreover, since 2008 WG2 has started the successful organization of self-sustaining intercomparison exercises, such as IC2008 [8], IC2009 [9,10,11], IC2010 [12], and more recently IC2012ph, IC2012n [13] and IC2014, as well as the organization of training courses since 2012 [14,15].

Towards the end of 2013, Council Directive 2013/59/EURATOM laying down the new European Basic Safety Standards was published [16]. Some challenges (e.g. monitoring of the lens of the eye, issues related to NORM industries, radon dosimetry) may still lie ahead and might deserve further attention in the coming years as its implementation is due from 2018. At the same time it is the aim of EURADOS itself to carry on performing regular IC exercises and training courses as well as periodic QA/QC surveys allowing the assessment of harmonization of individual monitoring [17].

1.2 2012 Survey

For the development of the above mentioned tasks WG2 relies on a network of contact persons comprising IMS, national dose registers (NDR) and authorities in general, in all Member States. To promote the continuous improvement of quality, in 2012 EURADOS WG2 carried out a survey of

IMSs in Europe. The survey followed a similar one [18] carried out in 2003, prior to the publication of RP160. The 2012 survey was prepared and issued nearly three years after the publication of RP160 and was therefore be expected to provide some information on its state of implementation. The survey provided the opportunity for more countries to be included, and also addressed some topics of current interest, e.g. eye lens dosimetry. In disseminating the results of the survey, WG2 aims to:

- promote harmonisation of IMS quality practice.
- help IMSs to achieve a minimum level of reliability.
- promote continuous improvement in individual monitoring.

The information gathered from the network of contacts has been collected and analysed.

1.3 2003 Survey - Summary

The 2003 survey obtained responses from 88 services in 26 European countries and the dosimetric services of the IAEA. The questionnaire covered a range of topics including:

- quality assurance/quality control.
- traceability.
- reporting and recording.
- lost dosemeters.
- sources of errors or increased uncertainty.

Full details are given in the report [18]. The findings included the following.

- A number of services, in particular smaller ones, were not familiar with aspects of:
  - QA and QC.
  - the importance of uncertainty in measurement.
  - traceability of calibrations to national and international standards.
- There was a continued need for initiatives on education and training in the field of individual monitoring.
- 97% of IMSs used the personal dose equivalent quantities $H_p(d)$.
- There was a conflict between the concepts of Recording Level and Reporting Level, as suggested by the ICRP, and the requirements of QA programmes such as those based on ISO 17025 [19].
- The loss of dosemeters by users had a high influence on the quality and reliability of the dose assignment.
- For improving the rate of unreturned dosemeters, the process of seeking dose estimates was more successful than that of increasing financial charges.
- Most general error conditions (e.g. damage, contamination and loss of data) were classified as rare.
- Most error conditions with a high impact, like irradiation of the dosemeter when not worn or wrong wearing position of the dosemeter, were out of the direct control of the services.

1.4 Glossary of Abbreviations

A glossary of all abbreviations used in this report is given after the references, near the end.

2 2012 Survey Method

2.1 Identifying Participants

The list of contacts was based on those approached for the EU-TRIMER project [20]. The survey was sent to 170 IMS, in 35 European countries, including the IAEA (United Nations).

2.2 Practicalities

A number of considerations influenced the design of the survey. Because participation by IMSs was voluntary, there was a need to minimise the time and effort required of them. Data entry had to be relatively easy, and available via a commonly-used package. Similarly, the data had to be easy to collate and to analyse. A Microsoft Excel spreadsheet was therefore chosen as the best means, and one of the team developed macros that allowed for efficient processing. The spreadsheet pages are shown in the Annex.

2.3 Focus

The survey questions focussed on practices that can influence quality and reliability, covering in particular dosimetric quality assurance and formal quality systems. There were also questions on dosimetry practice, including double dosimetry, eye lens dosimetry and reporting methods. To set these in context, information was gathered about the size of the IMS, the work sectors they covered and the methods they used. Finally, there was a section on common conditions that can impair dosimetry results, both in general and for the particular dosimetry techniques.

2.4 Execution

The survey was prepared, sent to all IMS and collected throughout 2012 and early 2013. In the main, there were few difficulties reported by the respondents. Apart from minor issues associated with differing versions of Excel and with enablement of macros, the only major problem was found by an IMS that did not use Microsoft products.

2.5 Reporting

A summary report was presented at the 17th Solid State Dosimetry Conference, Recife, Brazil, 2013 and has been published [21] in the journal *Radiation Measurements*. The present report expands on this, and contains full details of the analysis.

3 How Representative are the Data?

From the 170 IMS, 78 responses were received, from a total of 31 countries. This represented a similar response rate (46%) to the 2003 survey. Importantly, as in 2003, all of the larger services in Europe were represented. This meant that the proportion of workers covered by IMSs in the survey was much higher than the proportion of IMSs. The number of workers covered, at around 1 million, is close to the total estimated number of radiation workers in Europe [18,22].

Note that answers to some of the questions are based on the *number of IMSs*– there was no weighting for numbers of workers. As regards the reliability of the data, responses were checked for plausibility but, given the voluntary nature of the survey, the analysis is ultimately dependent on what has been supplied.

Another interesting point arose from the use of English in the survey. Every effort was made to make the meaning clear, and in the main, the responses showed that the questions had been understood. However, in some cases there was an element of confusion. For example, one question asked about reports sent by "mail", meaning paper copies sent in the post, but was understood by some as meaning "e-mail".

Main point

- **The survey has high validity.**

In the sections below, the letters in the subparagraph titles preceding each topic refer to the corresponding "box" in the survey spreadsheet (see Annex).

4 What Are the Individual Monitoring Services Like?

IMSs were asked to provide information on their size, the work sectors they covered, and the methods (types of dosemeter) they used. Services ranged from very small (fewer than 100 workers monitored) to very large (over 1.6 x 10^5 workers monitored), with the three largest services covering 40% of the workers monitored. Overall, across all responding IMSs, nearly 10^7 whole body, photon/electron dosemeters are issued per year.

4.1 A: Work sectors covered

The work sectors covered are shown in figure 1. The outstanding feature is the dominance of the medical sector, which accounts for well over half of all individual monitoring done in Europe. The pattern is similar to that observed in 2003 [18], with a small reduction in the medical sector and some increases in the dental and veterinary sectors.

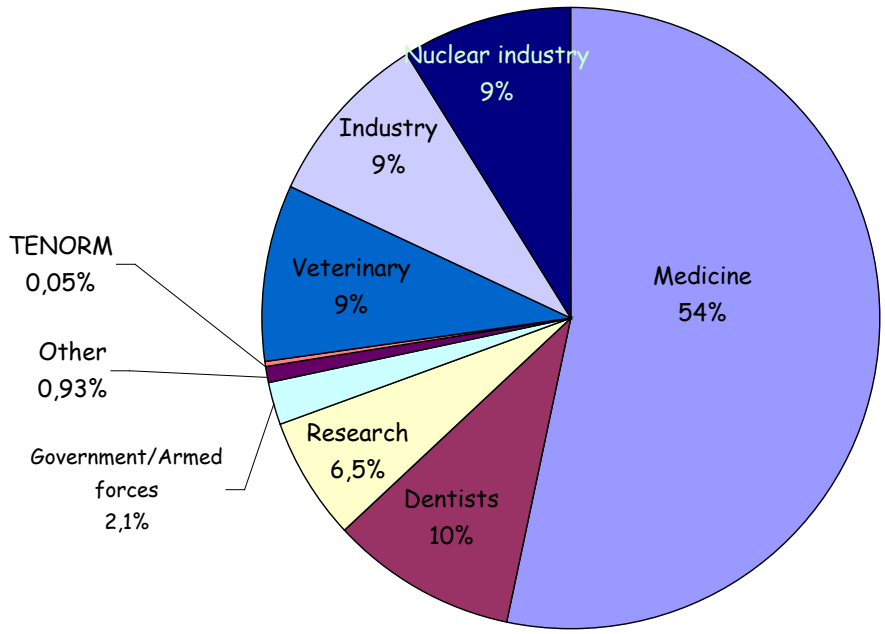

Figure 1. Work sectors represented by all IMSs. Percentages are based on the reported percentages and on the reported total number of workers

4.2 B and C: Size of services and origin of data

One measure of the size of the IMS is the number of individual workers that it monitors. On this basis, the size of the IMSs ranged from 72 persons monitored to over 167 000. The mean number of workers monitored was just over 16 000 (see Table 1), but the modal number of workers was less than 4 000. This shows that the mean is heavily weighted by a few large services, but that **most**

services monitor no more than a few thousand workers. Further inspection of the data shows that fewer than a third of the IMSs monitor more than 10 000 workers.

Another measure of size is the annual number of dosemeters issued by an IMS. Figure 2 shows the size distribution of IMSs by this measure. The typical service issues between 10 000 and 100 000 dosemeters per year, in line with the above findings. A few very large services issue over 1 000 000 per year.

Note:

- 72 IMSs (95%) reported the total number of workers.
- Some of these reported only an estimate of the number of workers monitored, amounting to 14% of the total.
- Statistics for category A workers are reported even though only 36 IMSs (47% of IMSs, 26% of workers) reported the number of A workers. The total and mean values are based only on those IMSs who reported a value.

Table 1: Number of workers

	Workers monitored	Category A workers	% of A workers
Total	**1 156 602**	124 037	
Mean (per IMS)	16 064	3 445	54%

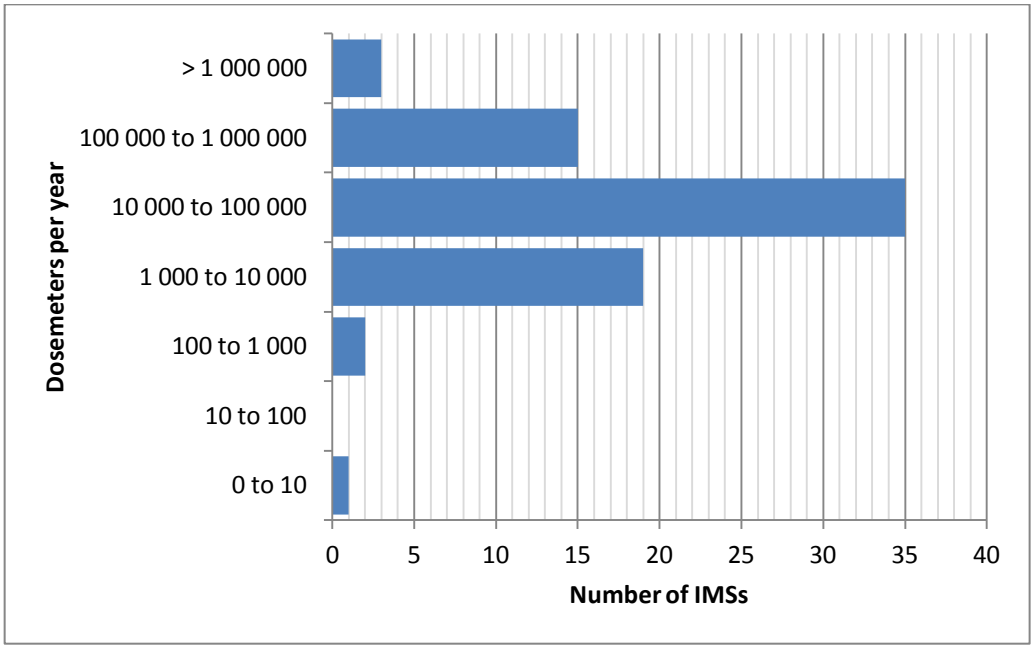

Figure 2. Sizes of the responding IMSs, in terms of annual number of dosemeters issued. Compare similar figure (also Figure 2) in 2003 survey [18].

4.3 D: Purpose, Types of dosemeter and change interval

4.3.1 Purpose

A grand total of 10.8 x 10^6 dosemeters are issued, over all the responding IMSs, yearly. Of these, almost 90% are used for X/beta/gamma radiation monitoring of the whole body – see Figure 3. Other dosemeters are used for measuring the photon/electron dose to the extremities, and for measuring the neutron dose to the whole body.

Extremity and eye lens dosimetry is now carried out by larger proportions of IMSs than in 2003. In that survey, 64% of IMSs carried out extremity dosimetry and only 11% eye lens dosimetry. In the present survey the respective percentages are 78% and 45% (see following figures).

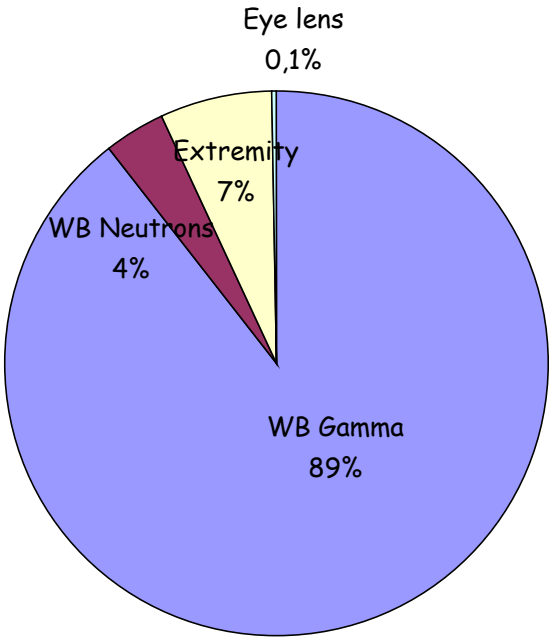

Figure 3a: Purposes for which dosemeters are issued, by proportion of all dosemeters.

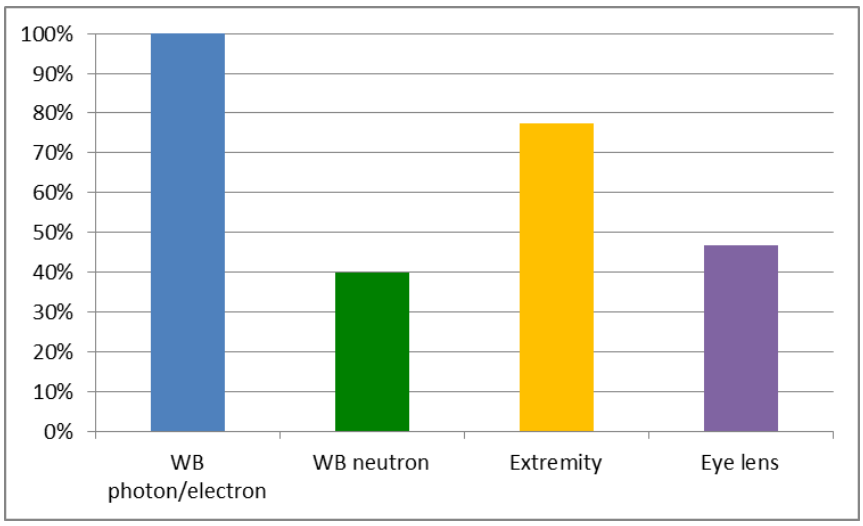

Figure 3b: Purposes for which dosemeters are issued, by proportion of responding IMSs.

4.3.2 Dosemeter Type (Method)

For whole body X/beta/gamma monitoring, more than 80% of the issued dosemeters are TLDs (40%) or films (42%), with other methods such as OSL, APD, DIS and RPL making up the remainder (mainly formed by RPL 34%). For neutron monitoring albedo TLDs (nearly 70%) predominate over track etch; and for extremity and eye lens monitoring, TLDs are used exclusively. See Figure 4.

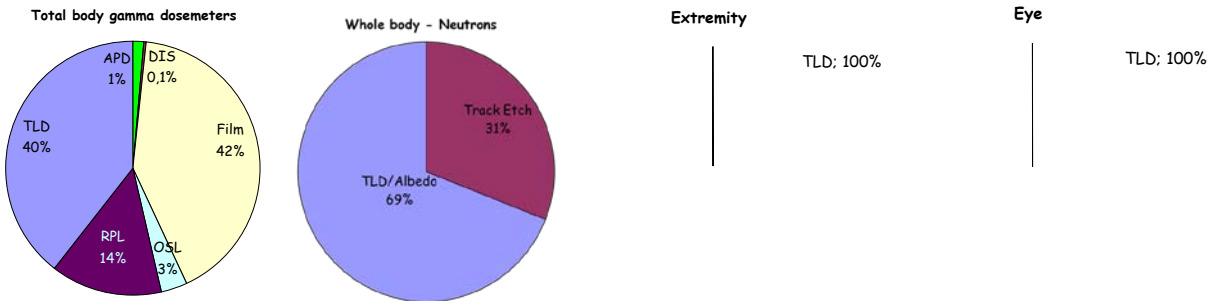

Figure 4. Proportions of dosemeter types used for each purpose.

It is interesting that film badge dosemeters remain in such wide use. With the global shift towards digital imaging, recent years have seen persistent problems in obtaining photographic film; so it is perhaps surprising that in 2012, film still accounted for the largest proportion (42%) of dosemeters issued. While the 2003 report [18] does not quote the number of films issued per year, it does show that 25 IMSs were issuing films. By 2012 this figure had fallen to 15, although this does include some of the larger services.

4.3.3 Change intervals

A variety of change intervals is used by the different IMSs: some are in multiples of weeks, from two to thirteen, whilst others are in multiples of months, from one to three. Meanwhile, for APDs, it is common practice to issue dosemeters for a very short period, e.g. a single shift. Therefore, in order to simplify the question on change intervals, IMSs were asked only to classify their change intervals as “short” (one month or less) or “long” (more than one month). As shown in Figure 5, dosemeters are mainly issued for a “short” monitoring periods. The exceptions are RPL dosemeters, and track etch dosemeters for whole body neutron monitoring.

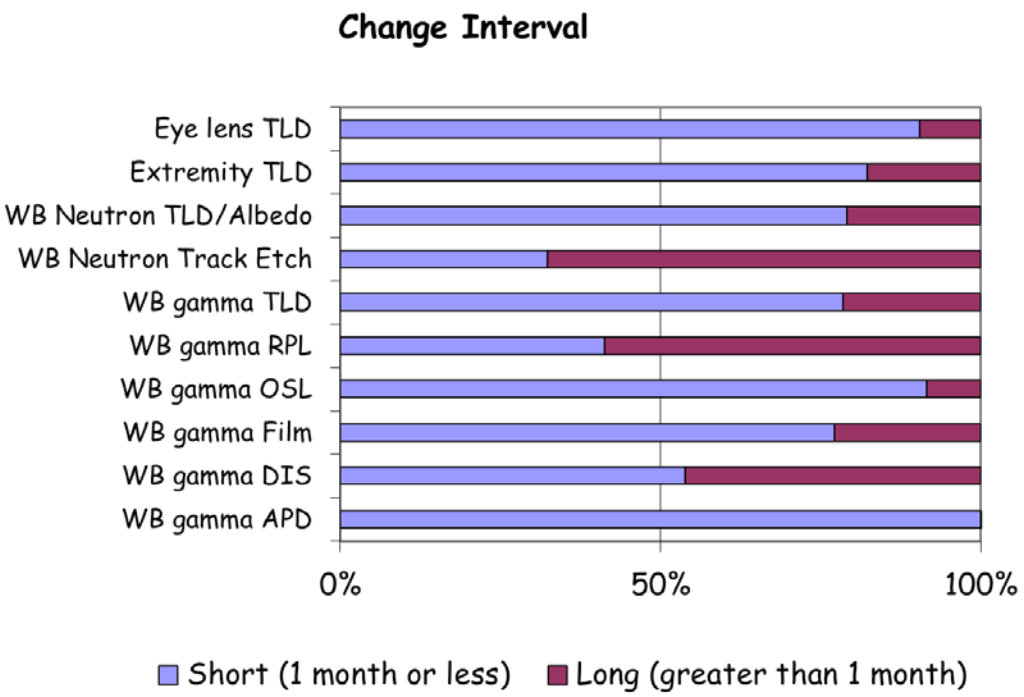

Figure 5. Proportion of change intervals by dosemeter type/ purpose.

Main points:

- **For whole body beta/gamma/x-ray monitoring, Film and TLD still dominate, but methods such as OSL and RPL are increasing in use.**
- **For neutron monitoring, albedo TLD and track etch methods are used.**
- **Only TLDs are used for extremity and eye lens monitoring.**
- **Change intervals of one month or less remain the most common.**

4.4 E: Lost and unreturned dosemeters

4.4.1 Loss rates

Not every dosemeter that is issued to an undertaking is returned to the IMS after use. The loss, or non-return, of dosemeters can cause problems in two ways. First, the missing dosemeter contains information about the worker's exposure – information that is important and that often cannot be retrieved. Second, the IMS has lost a valuable item that could have been issued to a subsequent worker. The missing item must be replaced, at a cost. Note that even for single-use dosemeters like film and some types of OSL, there will be a cost to the IMS in terms of replacement holders or filter packs besides the work done to deliver them.

Because some dosemeters are returned late – some very late – a decision is needed on when a dosemeter should be declared as "lost". For the purposes of the survey, IMSs were asked for the proportion of dosemeters that were still not returned **six months** after the end of the wear period. The frequency distribution amongst the responding IMSs is shown in Figure 6:

- The proportion of dosemeters issued that are not returned for reading within 6 months is variable.
- The mean fraction of lost dosemeters (averaged among services) is 2.4%.
- 70% of IMSs reported a fraction lower than 3%.

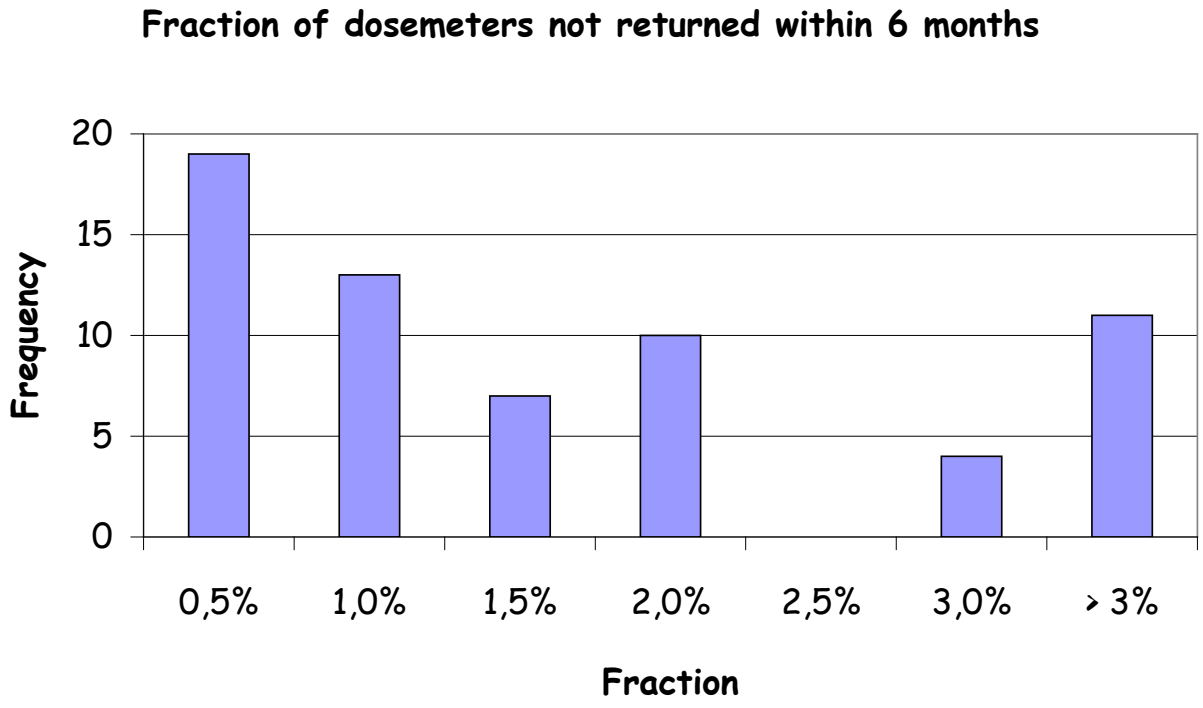

Figure 6. Number of IMSs experiencing different dosemeter loss rates. IMSs experiencing loss rates in excess of 3% are counted together.

4.4.2 Charges for lost dosemeters

Many IMSs recover the costs of lost dosemeters by passing the charge on to the undertaking, and the questionnaire asked IMSs to give the standard charge in Euros. There was a substantial variation in practice.

- The charges made by most IMSs ranged from €0 to €100. (One service reported that it charges as much as €300.)
- The mean charge was €37, and the median €28.

By means of these charges, the undertaking is penalised for the loss of the dosemeters. It might be thought, then, that increasing the charge might cause undertakings to return more dosemeters – in other words, that there would be an inverse correlation between the penalty charge and the loss rate. However, the 2003 survey [18] found no such correlation: the loss rate was unaffected by higher penalty charges. That finding is repeated in the present study, as shown in Figure 7. There is no correlation between the fraction of dosemeters that are not returned for reading and the amount charged (in euros).

One question that was not asked in the survey was whether the charge for non-returned dosemeters is imposed on the worker, or on the undertaking. Had it been, the answer would have indicated whether passing the charge on to the worker is more effective.

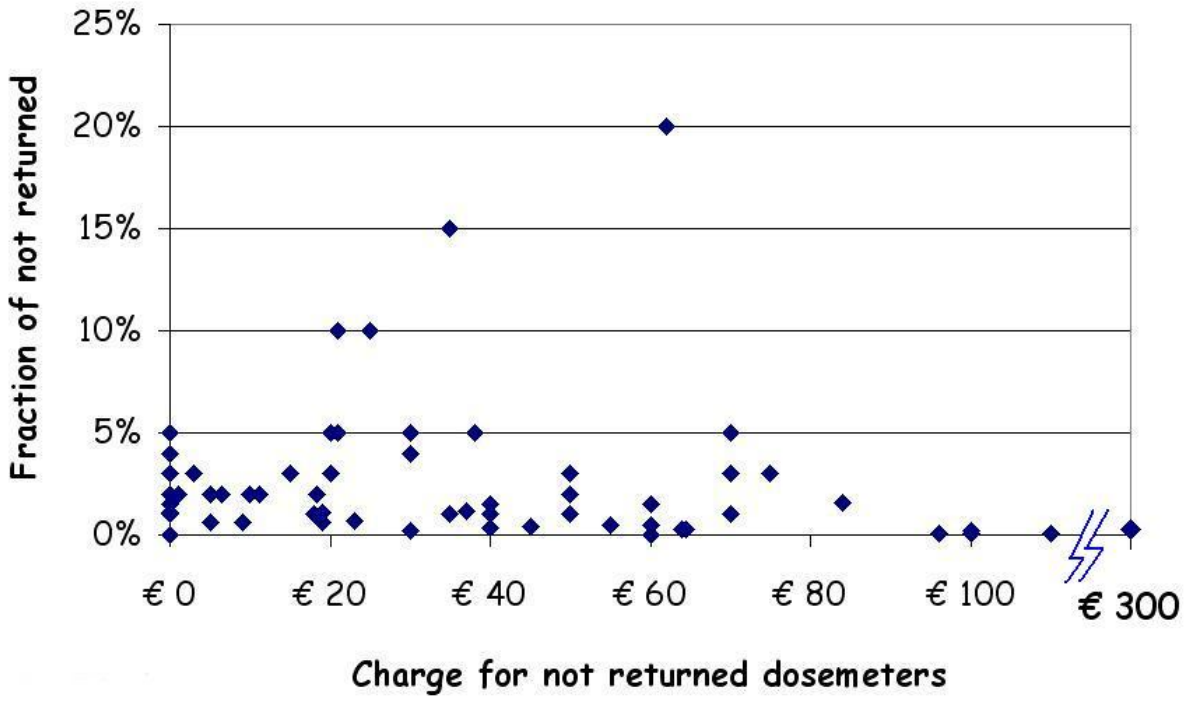

Figure 7. No correlation between charge for lost dosemeters and the rate of loss.

Main points:

- **Typical loss (non-return) rates vary between 0% and 3%, although 11% of IMSs experience higher rates.**
- **The mean loss rate is 2.4%**
- **The median charge for a lost dosemeter is €28.**
- **The amount of the charge does not influence the loss rate.**

5. Formal Quality Systems

5.1 F: Quality Management Systems

IMSs were asked to choose between the quality management standard ISO 17025 [19] and the ISO 9000 family of standards [23], or to indicate what other QA system they used. The questions asked whether services were accredited (i.e. they actually hold a certificate) or compliant (i.e. they comply with all requirements), but both answers were allowed. Note also that some services reported accreditation or compliance with both standards. Taking all answers together, an encouraging 70% of responding IMSs were accredited to one or other of those standards, while the proportion of IMSs reporting *either* compliance *or* accreditation to either of the standards was 91%.

In the "Other" category, five services quoted accreditation to national requirements. Two services misunderstood the difference between type test and quality management standards, quoting the former ISO 1757 (for film badges) and IEC 61066 (for TLDs). Three services quoted ISO/IEC 17020 [24], which specifies requirements for the competence of bodies that perform inspections, and is therefore not appropriate for laboratory QMS.

Table 2. Use of quality management standards.

Quality Management Standard/ Attainment	Proportion of IMSs
Accredited, ISO 9000 family	30%
Accredited, ISO 17025	45%
Accredited, ISO 9000 family OR ISO 17025	70%
Accredited OR compliant, ISO 9000 family	41%
Accredited OR compliant, ISO 17025	68%
Accredited OR compliant, ISO 9000 family OR ISO 17025	91%

Services were also asked about conformity to EU or IAEA technical recommendations. 54% reported that they were compliant with at least one of these, with 39% reporting compliance with RP160.

Compared to the results of the 2003 survey, the new results show a significant increase in the use of formal quality systems by IMSs. There is now wide recognition of the need for, and benefits of, effective quality management in delivering reliable personal dosimetry. The increased awareness must be at least partly attributable to the efforts of EURADOS, through:

- dissemination of the 2003 survey results.
- publication of RP160 [7] recommendations.
- regular intercomparison exercises [8,9,10,11,12,13].
- training courses [14,15].

Main points:

- **a high proportion of services reported compliance with, or accreditation to, one of the ISO QA standard documents.**
- **ISO 17025 was quoted about 60% more often than ISO 9000.**
- **a few IMS are accredited to national requirements.**
- **more than half of the services reported compliance with EU or IAEA technical recommendations.**
- **a few IMS are confused between quality management standards and other standards (such as those for type testing).**

5.2 G: Quality Audits

These questions asked what formal quality audits were undergone by IMSs, and at what frequency.

74% of IMSs carry out internal audits. Nearly half are subject to audits under national requirements, and nearly two-thirds undergo audits under formal quality management systems such as ISO 17025 and ISO 9001 (see Figure 8). Note that these categories are not mutually exclusive, and IMSs could undergo all three. Three IMSs misunderstood the question, taking it to refer to proficiency testing (intercomparisons).

IMSs were asked how often these audits took place. The typical interval between audits was 12 months, though in some cases it was significantly longer.

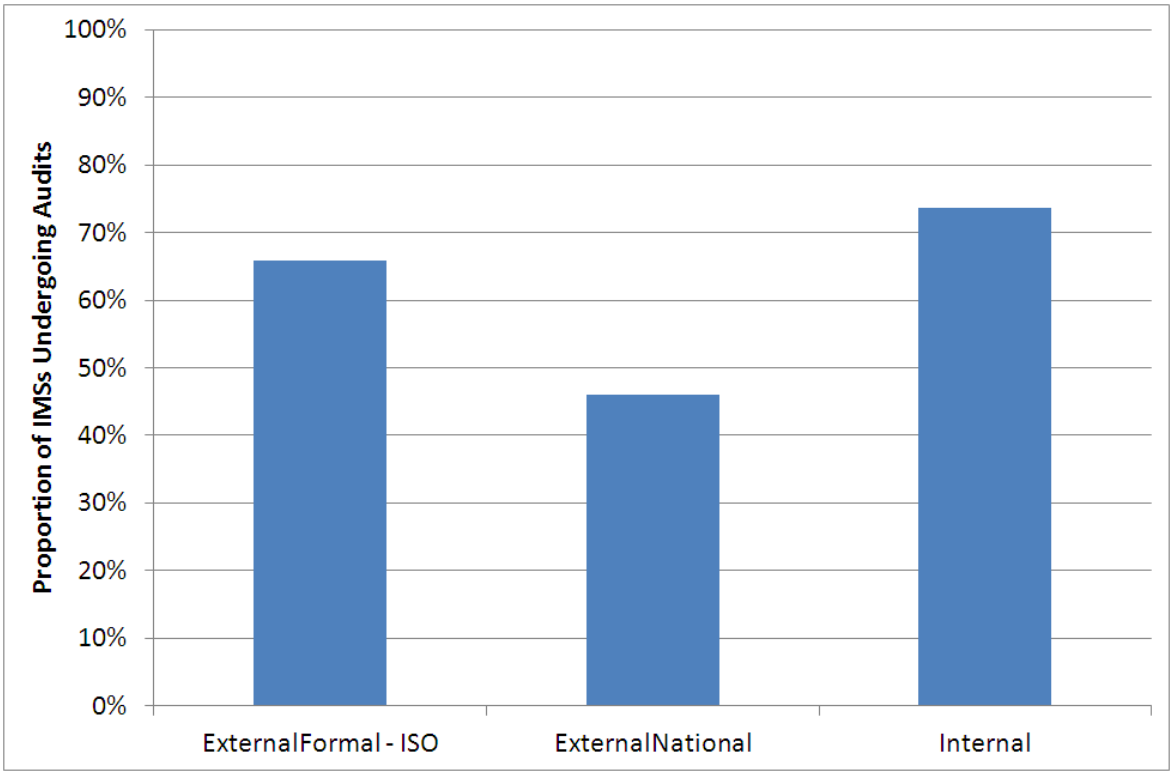

Figure 8. Quality System Audits undergone by IMSs

Table 3. Audit intervals, in months

	Minimum	Mode	Maximum
External Formal (e.g. ISO 17025, ISO 9001 etc.)	12	12	36
External National (e.g. regulator)	1	12	72
Internal	1	12	36

Note that typical ISO 17025 or ISO 9001 arrangements would see an internal audit programme that takes 12 months to complete, with some aspect of the standard being audited each month, as well as annual external audits.

5.3 H: Declaration of Compliance

21 IMSs (28% of the sample) have to make an annual declaration of quality/ compliance. Of these, 7 make the declaration to the regulator and the remainder to the approval or accreditation body.

Main points:

- **There is wide acceptance of the importance of audit – 74% of services have internal audits, and two-thirds undergo formal, external QMS audits.**
- **The typical interval between external audits is 12 months.**
- **National regulatory requirements vary. Some audit very frequently, others infrequently.**
- **Internal QM procedures and practices also vary in the various IMSs.**
- **A substantial minority of IMSs are required to make an annual declaration of compliance.**

6 QA in Dosimetry

6.1 I: Type Testing

RP160 [7] points out (in Chapter 7) that is essential for every IMSs to know how their dosemeters behave in a variety of radiation fields and environmental conditions, specifically recommending that "every type of dosemeter issued by an ADS (Approved Dosimetry Service) or IMS should be fully tested and the results of these tests made available to users and potential users."

The process of obtaining this information is known as **type testing**. Some IMSs will carry out their own type testing, especially if they are using their own dosemeter designs, whilst others will rely on tests carried out by the manufacturer or a national body. Type tests are often carried out against international standards [25,26,27,28], but this is not always the case.

This survey question sought to establish what type testing was being done, and against what standards. Again, IMSs were allowed to provide multiple answers, e.g. if they used more than one type of dosemeter.

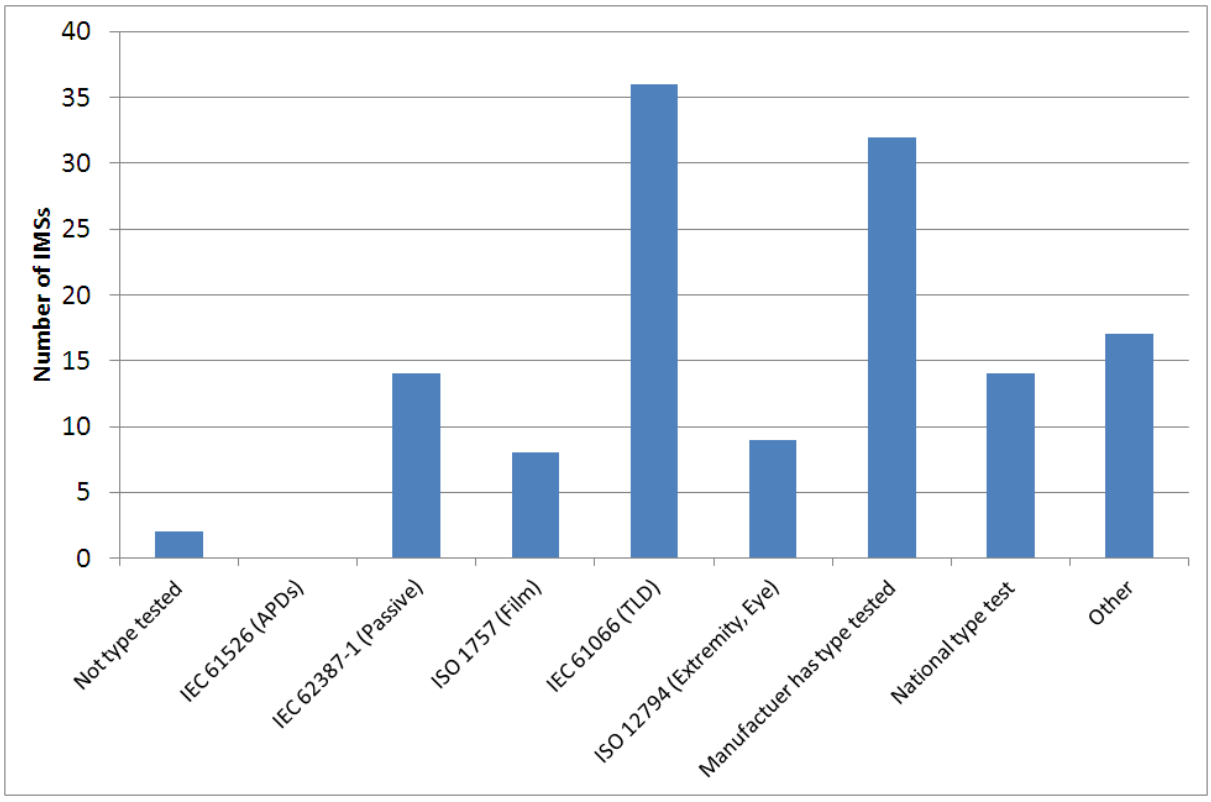

Figure 9. Type test standards used by IMSs. (Note: ISO 1757 and IEC 61066 have been superseded by IEC 62387-1.)

A high proportion of IMSs using TLDs or film badges have type-tested against an appropriate standard. However, only 16% of services that use extremity dosemeters have tested against ISO 12794 [28] (which is currently being revised). About one third of all IMSs rely on manufacturer type tests, and about 20% rely on national type test procedures.

Of the "other" answers:

- one IMS had tested its neutron dosemeter against ISO 21909 [27][1].
- two IMSs quoted inappropriate standards.
- two IMSs quoted "internal procedures".

IMSs were also invited to comment on tests they had omitted from the type test standards, and on tests they had added. No major trends were observed, but amongst the tests omitted by IMSs were those on TLD reader machines (as distinct from the dosemeters).

Main points

- **91% of IMSs use dosemeters that have undergone formal or recognised type testing.**
- **97% of IMSs use dosemeters that have undergone any type testing.**
- **the importance of type testing is widely accepted.**

6.2 J: Traceability

6.2.1 Route

Traceability to national (or international) standards is also essential for accurate dosimetry. IMSs were asked to indicate if their main traceability route was via a primary standards laboratory, a secondary standards laboratory, via "European Accreditation", or another route. The small number of "other route" answers were effectively via tertiary standards. Some IMSs gave more than one answer. In all, 71 of the 76 services (93%) stated that they had some traceability route. Of the remainder, most had not answered the question.

As shown below, the commonest traceability route was via a secondary standard laboratory. One further point of note is that not all IMSs have ready access to a standards laboratory. This is likely to be a factor behind some of the choices, and will also affect the interval between checks (6.2.2).

[1] The reason for this low usage of ISO 21909 is not clear. It may be that most respondents took this question to apply only to photon/electron dosemeters; it may be that the high costs involved in type-testing for neutrons are difficult to justify; or there may be no national requirement for full testing.

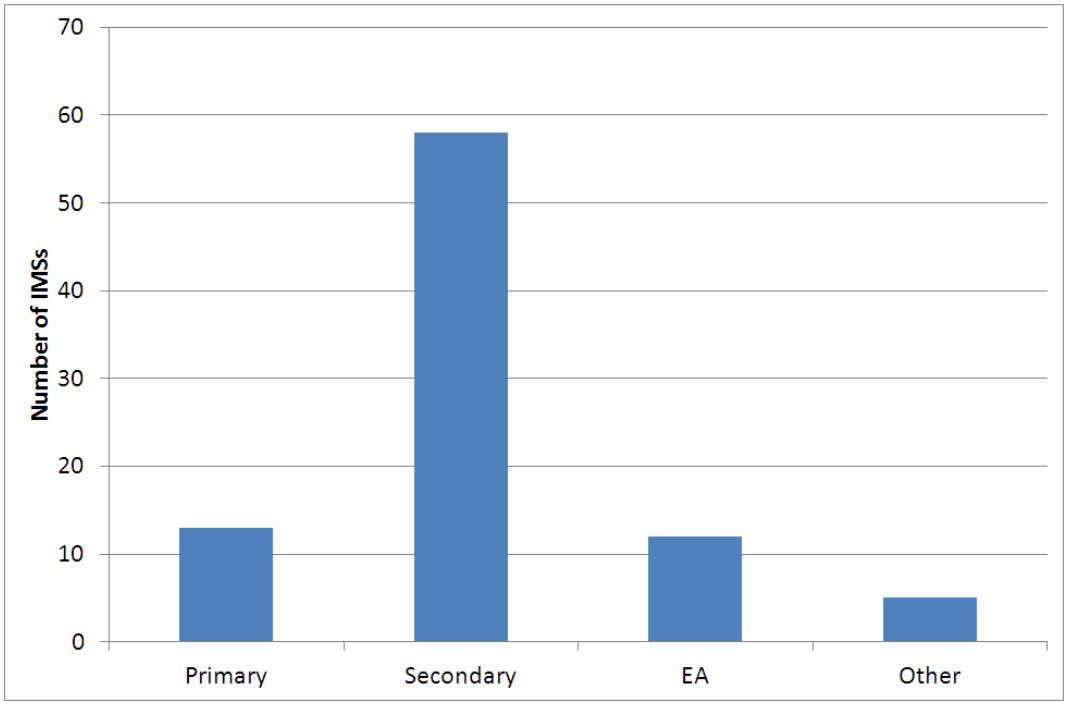

Figure 10. Traceability routes quoted by IMSs

6.2.2 *Interval*

IMSs were also asked about the interval between traceability exercises.

- 7 services said they only checked traceability when there is a change to the system.
- 1 service said they had no plan for checking traceability.
- 66 services checked their traceability routinely. Of these:
  - the modal interval was 12 months.
  - the mean interval was 15 months.
  - intervals ranged from 1 month to 48 months.

6.2.3 *RP160 Recommendation*

RP160 [7] refers to traceability under the term "reference calibration". It recommends, in Chapter 7:

- "For a fully tested dosemeter or dosimetry system, a reference calibration . . . is sufficient to ensure absolute dose measurements traceable to national dose standards."
- "The reference calibration of the dosimetry system **should be repeated at regular intervals**, for example every two years."

Traceability should also be a condition for approval (Chapter 8).

Main points:

- **most services have established traceability.**
- **the typical interval between traceability exercises is 12 months.**
- **services should compare their practice with the RP160 recommendations.**

6.3 K: Performance Testing For Approval

6.3.1 General

Regulatory authorities usually require some evidence that an IMS is able to produce accurate results. This evidence is usually obtained by means of "blind" tests, in which the IMS is required to assess dosemeters that have been given secret doses by an external body. National requirements fall into the categories shown in Table 4.

Table 4. Types of performance testing for regulatory approval

"Part-blind"	A test is announced. The IMS knows which radiation qualities are to be used, but not the doses.
Blind	A test is announced. The IMS knows neither the radiation qualities nor the doses.
"Surprise"	A blind test that is unannounced: the inspector arrives without warning, bringing the dosemeters to be assessed, and witnesses the test.
None, but evidence of proficiency testing	ISO 17025 [19] requires laboratories to undertake proficiency testing of some kind. Some national authorities rely on this provision, with inspectors making a judgement on whether the proficiency testing is adequate.

70% of IMSs stated that some kind of performance testing was required. (In some of the cases where no performance testing was required, this was because the IMS was itself run by the only national organisation capable of administering the test.)

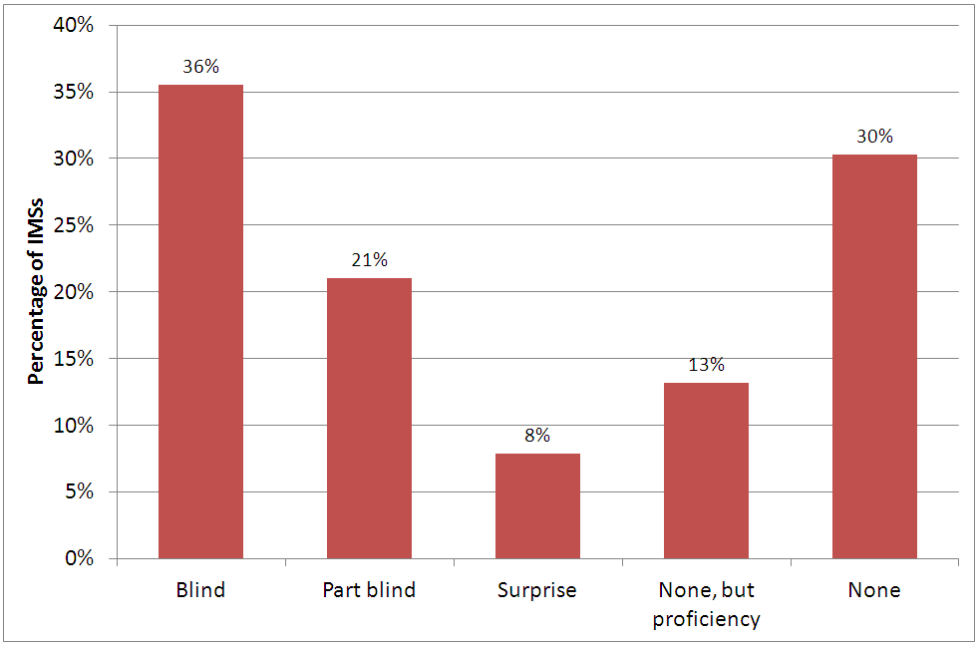

Figure 11. Methods of Performance Testing for Approval – IMSs. Percentages do not add up to 100 because a few IMSs are subject to more than one kind of test.

6.3.2 Interval

The typical (modal) interval between regulatory performance tests was 12 months, but intervals could be anywhere from 1 month to 5 years, with an average of 18 months.

Main points

- **70% of IMSs have to undergo some kind of regulatory performance testing.**
- **for 13% of IMSs, the regulator requires no specific tests but instead relies on evidence of proficiency testing (see below).**
- **full "blind" tests are the most commonly required.**

6.4 L: Proficiency Testing

6.4.1 General

Proficiency testing includes not only compulsory activities such as performance testing, but also a range of voluntary activities. It is different from routine quality control/ quality assurance, in that it will normally test the whole system rather than just one aspect of it. ISO 17025 [19] requires that the proficiency testing chosen by a laboratory must be suitable, so IMSs must bear this in mind when selecting proficiency tests.

The possible approaches to voluntary proficiency testing were:

- international intercomparisons.
- national intercomparisons.
- internal dummy customer subscription [29].

Regulatory performance testing can also be regarded as proficiency testing.

68 services (89%) reported carrying out some kind of proficiency testing. A number of services used more than one approach, and six services used all three approaches. The "other" answers included one IMS who depended on the regulatory performance test, and two who referred to other internal procedures. See Figure 12.

6.4.2 Intercomparisons

The popularity of international exercises is clear, no doubt partly owing to the availability of EURADOS intercomparisons. Some IMSs also have access to national intercomparison programmes.

6.4.3 Dummy Customer

Notably, the use of internal "dummy customer" subscription was low, at only 14%. This is puzzling, because it is easier and cheaper to do than an intercomparison, although it is less demonstrably independent. It involves the issue of dosemeters to a member of the same organisation, e.g. someone with QA/QC responsibilities, through normal customer channels [29]. The dosemeters are given some treatment, which can be:

- dosing, in a fixed condition or a variety of conditions.

- leaving un-dosed, to test detection limits etc.
- exposure to different environments.

The dosemeters are returned through routine customer channels, and, finally, a report is issued in the same way. The method can be used by any IMS, and can be especially helpful if there is limited access to intercomparisons. And even if the IMS does enter intercomparisons regularly, the dummy customer method can still yield a lot of useful information.

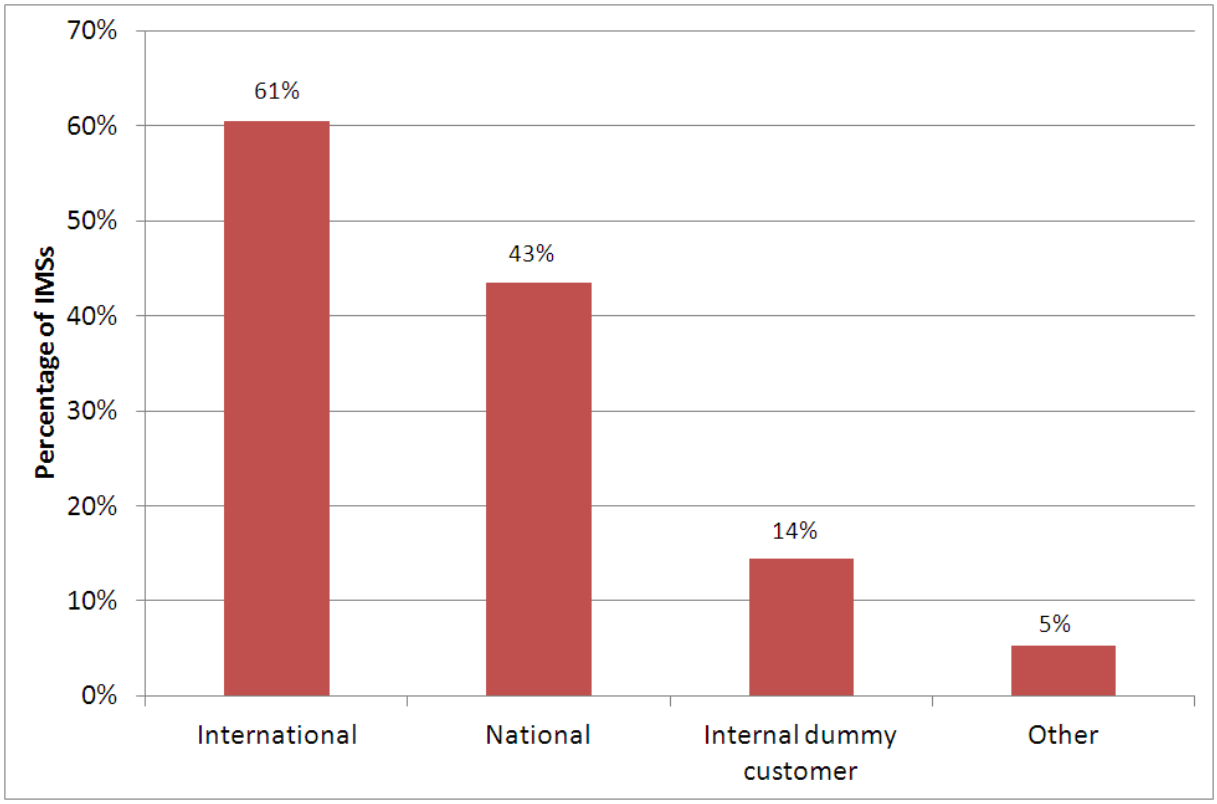

Figure 12. Methods of Proficiency Testing – IMSs. Percentages do not add up to 100 because some IMSs use more than one kind of test.

Main points

- **most services (89%) carry out some kind of proficiency testing.**
- **the most popular method is "international intercomparison" – no doubt owing to the ready availability of intercomparisons through EURADOS in recent years [8,9,10,11,12, 13].**
- **86% of IMSs report that they do not use a "dummy customer" subscription, even though this is an easy method.**

7 Dosimetry Practice

IMSs were asked several questions about practices when using dosemeters. It was clear that some issues are not under the control of IMS but given from authorities or in national legislation.

7.1 M: Lead Aprons

There are several ways to assess effective dose when a lead apron is used, e.g. in medical interventional procedures. The procedure varies from country to country as well as between IMSs.

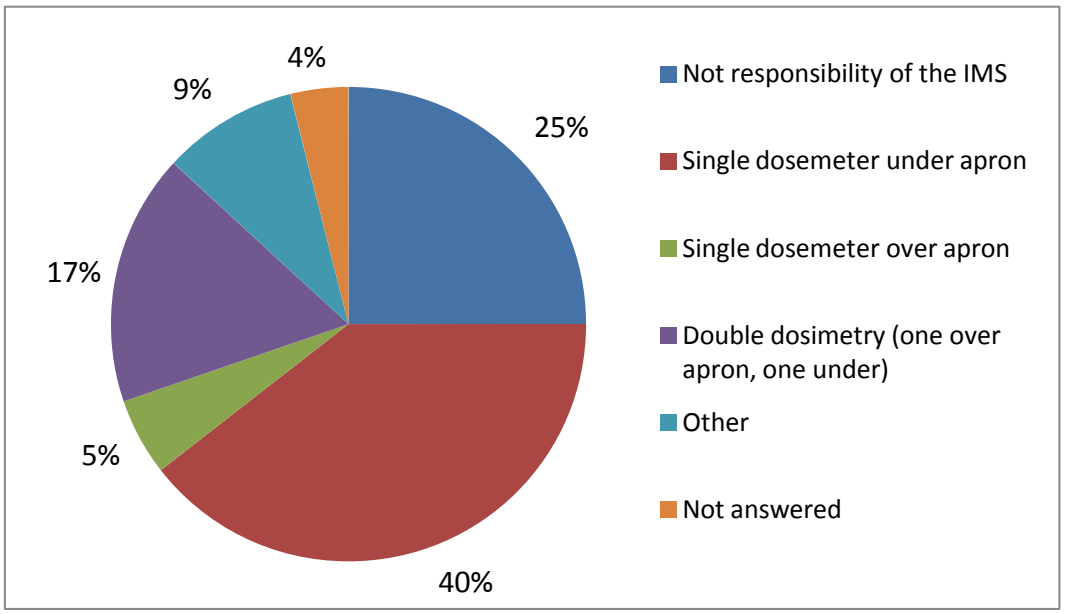

Figure 13. Methods of assessing effective dose when lead apron is used.

The most common way to assess dose when lead apron is used, is to use only one dosemeter under the apron. A quarter of IMSs report that it is not the responsibility of IMS to assess effective dose – they just report the measured dose.

17 per cent of IMSs report that double dosimetry (one over the apron and one under the apron) is used. Half of these IMSs are using same kind of algorithms [30]:

- When thyroid shield is used: $E = 1 * H_{(under)} + 0.05 * H_{(over)}$
- When thyroid shield is not used: $E = 1 * H_{(under)} + 0.1 * H_{(over)}$

If the answer was "Other", in most cases workers do not use a lead apron at all.

Main points:

- **the commonest approach is to use a single dosemeter under the apron.**
- **there is some agreement on choice of algorithm, where these are used.**

7.2 N: Same-hand extremity dosemeters

IMSs were asked if there are some workers who use more than one extremity dosemeter on the same hand at the same time.

Only 16% of respondents indicated that workers may use more than one dosemeter. Two-thirds of these IMSs use highest measured dose to represent hand dose.

Main point:

- **in the few cases where more than one extremity dosemeter is used on the same hand, the normal approach is to take the higest dose as the equivalent dose to the hand.**

7.3 O: Eye lens dosimetry

About 40% of IMSs evaluate doses to the lens of the eye. IMSs that are measuring eye lens doses are in most cases (1 exception) measuring doses which are caused by photons. Slightly more than half of these are measuring also doses caused by electrons.

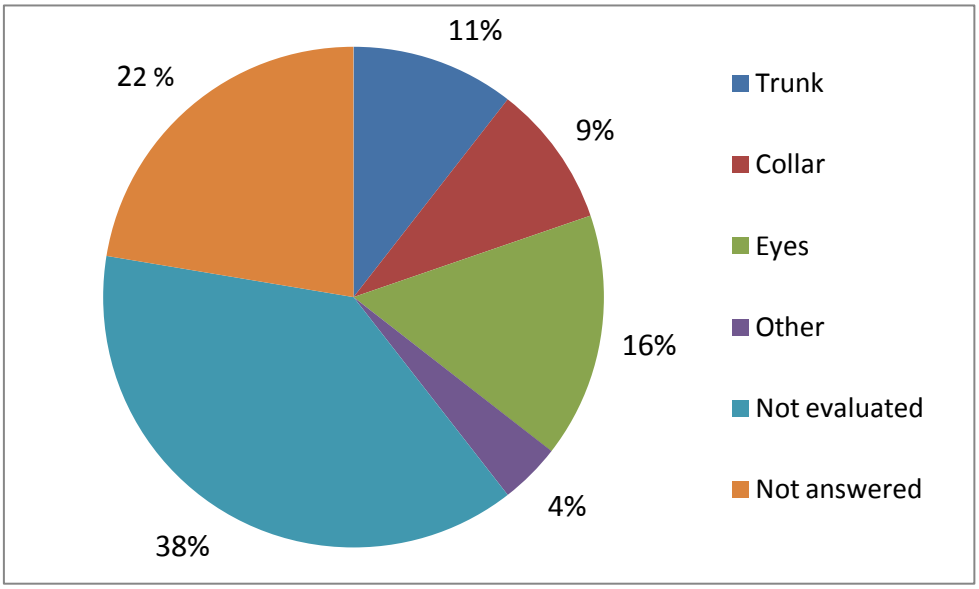

Figure 14. Methods how the dose to the lens of the eye is evaluated (dosemeter wearing position).

The most common way to evaluate the dose to lens of the eye is to use specific dosemeter for eyes. The others use dosemeters attached to trunk or collar.

For photons, quantities $H_p(0.07)$ and $H_p(3)$ are used, and $H_p(0.07)$ is slightly more popular than $H_p(3)$. There are also a few IMS using $H_p(10)$ for photons. For electrons, the quantities $H_p(0.07)$ and $H_p(3)$ are used, by about half of the respondents in each case.

Note that the reliance on $H_p(0.07)$ to assess eye lens doses from electrons can lead to significant over-estimates; for example, the range of ^{90}Sr beta particles in tissue is around 2 mm, so these will

contribute to $H_p(0.07)$ but not to $H_p(3)$. If the eye lens dosemeter is a thin one, as would be ideal for $H_p(0.07)$, this could be a problem. However, a number of systems use thicker detectors, which although calibrated for measuring $H_p(0.07)$ – typically from photons – do not properly measure that quantity for electrons, owing to the effective thickness of the detector. Nevertheless, care is needed.

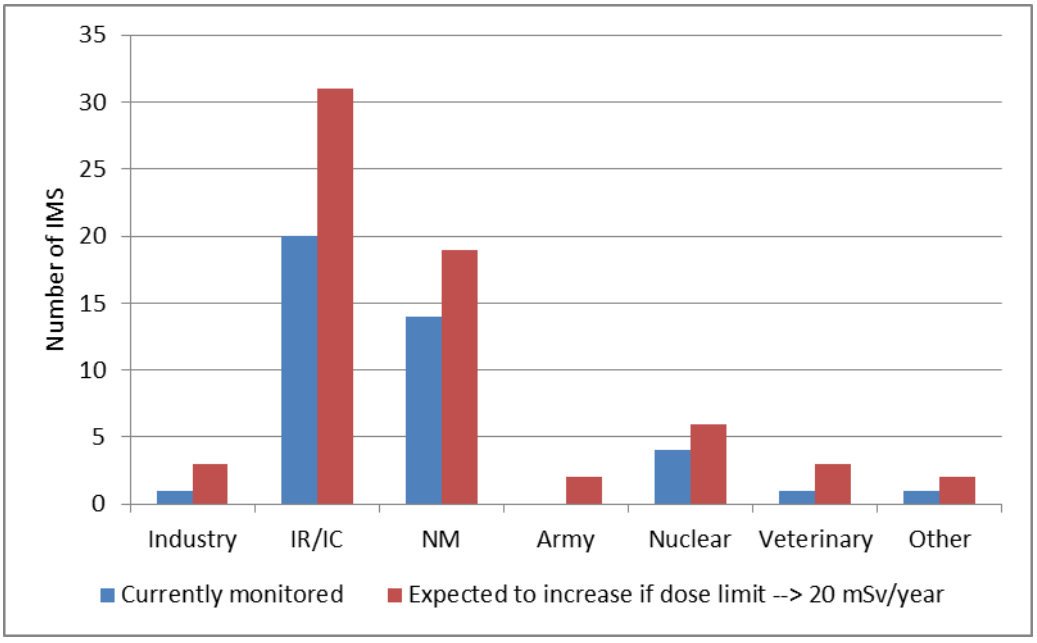

Figure 15. Monitoring of the eye lens doses in different sectors.

Currently, eye lens doses are most regularly monitored in interventional radiology and interventional cardiology as well as in nuclear medicine. In the future, when dose limit for lens of eye will decrease to 20 mSv/year [16], monitoring of the eye lens doses is expected to increase in most fields of activity.

Note again that Figure 15 shows the *number of IMSs* who carry out eye lens monitoring – not the number of workers who are monitored.

Main points:

- **a variety of approaches are used to measure eye lens dose.**
- **some IMSs measure $H_p(0.07)$, which is acceptable for photons but not for electrons.**
- **the medical sectors (IR/IC and NM) account for most eye lens monitoring.**
- **IMSs expect demand for monitoring to increase in most sectors, when the new dose limit is adopted.**

7.4 P: Parallel dosimetry

In view of the then-imminent publication of an ISO standard on the subject [31], IMSs were asked if there are situations in which workers wear dosemeters provided by two different IMSs at the same

time. One-third of IMS indicated that these situations exist, other one-third indicated that kind of situations do not exist and last one-third did not respond.

In the case of parallel dosimetry, the dose measured by the appointed IMS is most commonly used as an official value of *E*. None of the IMS indicated that higher value is used as an official value of *E*.

Only 16% of IMS indicated that guidance on parallel dosimetry would be useful and only a few (4) of those IMSs had faced that kind of situation.

One area in which questions of parallel dosimetry can arise is where outside workers move between the premises of different undertakings. The employer of the outside workers may have a contract with one IMS, while each client undertaking may use different IMSs. This can result in the worker being provided with two dosemeters at the same time. In particular this can occur on nuclear sites, where active dosemeters may be used as well as passive. Historically, the active dosemeter has provided dose and dose rate alarm capability while the passive dosemeter has been the dosemeter of record; but in recent years it has become possible to use active dosemeters for "legal" monitoring [32,33]

Main points

- **a third of respondents said that parallel dosimetry is routinely encountered.**
- **it is normally the result from the appointed IMS that is recorded for official purposes.**

7.5 Q: Pregnant workers

IMSs were also asked how dose for fetus is measured during pregnancy.

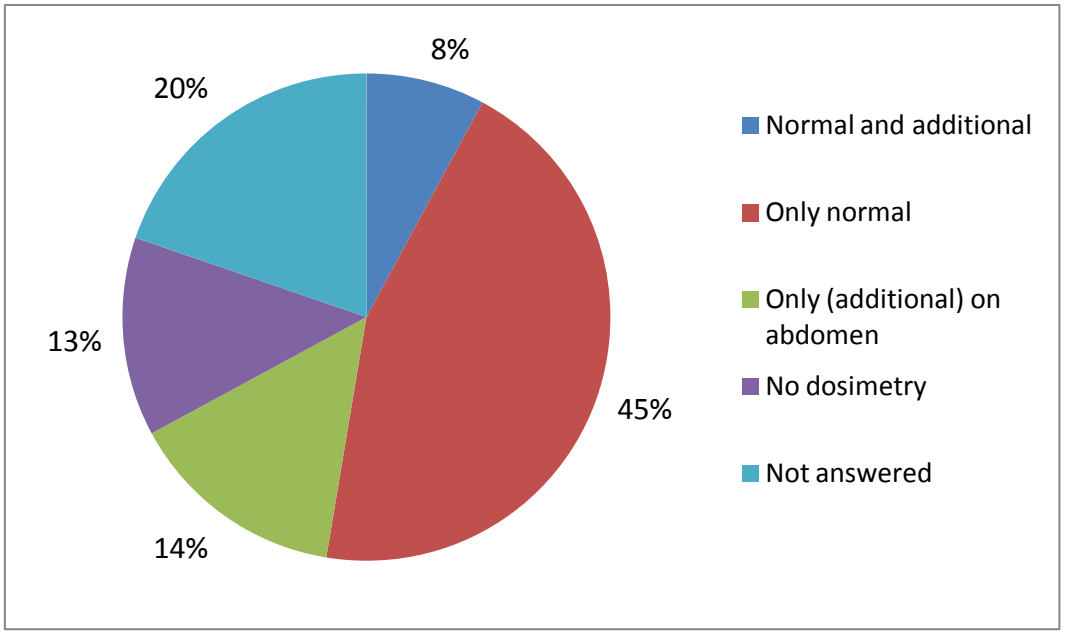

Figure 16. Measuring doses for fetus: which dosemeter pregnant workers use?

Almost half, 45%, of respondents indicated that only the normal whole body dosemeter is used and 22% indicated that a separate abdomen dosemeter is used (with or without normal).

There was a number of answers, 17%, where national legislation prohibits pregnant women from working with radiation, or where in practice pregnant women will not continue in radiation work.

Main point:

- **there are a variety of national approaches to monitoring dose to the fetus.**

8 Dose Reporting & Recording

8.1 R and S: Summation of doses (Co-ordination)

In those situations where an exposed worker is monitored by different IMSs (for example one IMS monitors for external exposure and another for internal exposure), more than one dosimetric report will be produced. The European Directives 96/29/Euratom [1] and 2013/59/Euratom [16] do not specify who will sum the doses.

More information on this issue is given in RP160 [7], which recommends that "the worker should be aware of the dose results received in relation to the work he has performed, particularly if monitored by two different ADS, for example when a person works at more than one location and may get dose results from different ADS. There could be a role for the NDR in these circumstances for communicating dose results to the individual."

According to the ESOREX report from 2010 [22], most countries in Europe declared that they have implemented a National Dose Register and that they are using it as a support to the regulatory authorities to perform statistical analysis, data storage and to issue, on request, the individual reports on occupational exposure which will give information on the doses reported by all IMSs which monitored the exposed worker.

The results of the EURADOS survey show that 45% of the participants answered that the National Dose Registry sums the doses that come from different IMSs. 12% reported that this is not done. Other answers included different cases from the ones selected for the survey, such as there is only one IMS in their country so there is no need for another institution to sum the doses. Other cases reported by the participants are that the undertaking or the occupational physician sums the doses.

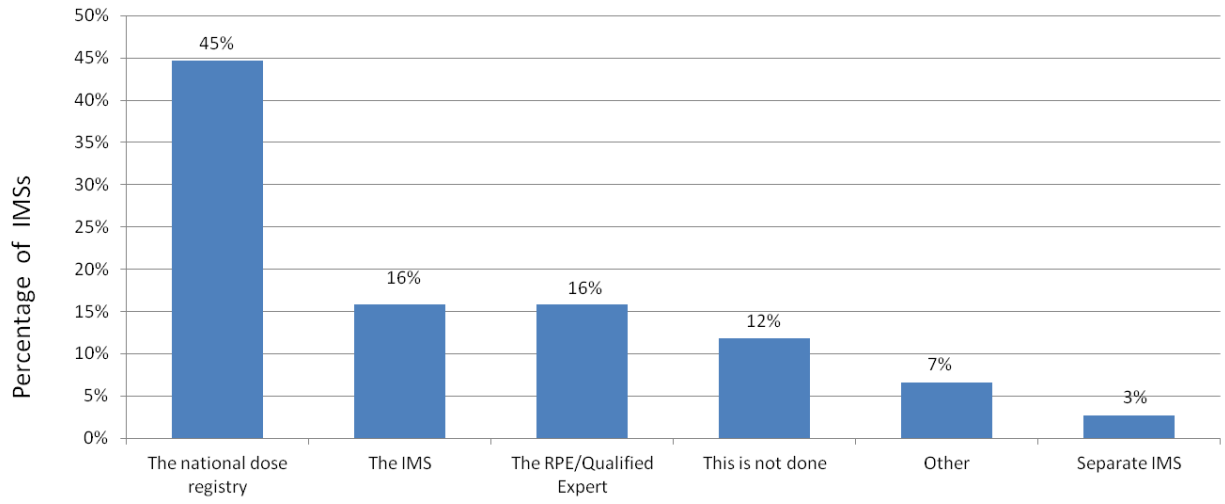

Figure 17. Distribution of the participants' answers on who sums the doses from different IMSs

In case of different employments for the same worker, 50% of the participants reported that the NDR sums the doses, 20% reported that this is the IMS responsibility and 14% reported that it is the

radiation protection expert (RPE)'s responsibility. Other participants reported that the approved occupational health service sums the doses or that there is only one IMS in the country.

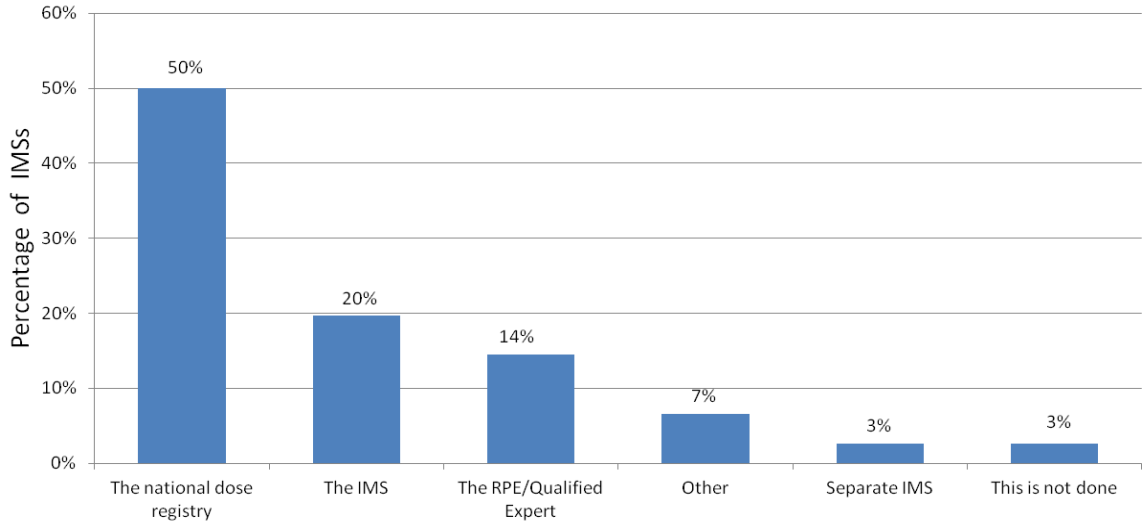

Figure 18. Distribution of the participants' answers on who sums the doses from different **employments** for the same worker

Main point:

- **in most cases, the responsibility for summing doses from (a) different IMSs and (b) different employments is decided by national arrangements.**

8.2 T: Who receives the reports

According to IAEA Safety Standard RS-G-1.3 [34] paragraph 8.3 "The purpose of record keeping, the nature and scope of the records that are kept, the extent of records keeping systems and the information provided are influenced by national requirements". This is also a sensitive case as the dose reports contain classified information and the Directives concerning the processing and privacy of personal data should be applied. RP160 [7] recommends that the dose reports should be made available only to a restricted number of persons (the undertaking, the authorities, the worker and the approved occupational health service). The European Directive 96/29/Euratom [1] states that: "The results of the individual monitoring required by Articles 25, 26 and 27 shall be: (a) made available to the competent authorities, and to the undertaking; (b) made available to the worker concerned in accordance with Article 38 (2); (c) submitted to the approved medical practitioner or approved occupational health services in order to interpret their implications for human health, as provided in Article 31."

Regarding the dose that should be reported (dose for the monitoring period, cumulative dose, components of dose), RP160 recommends that the report should include the dose values measured in the period, $H_p(10)$ and $H_p(0.07)$, and the accumulated dose (annual and/or 5-year accumulated dose) expressed on both quantities.

According to the results of the survey, 88% of the participants answered that the person who receives the dose reports is the undertaking (employer) or the radiation protection expert (RPE). Also, 64% of the participants report to the NDR. 5% of the participants answered that they report to the workers or to the authorities if the dose is higher than 2 mSv/month.

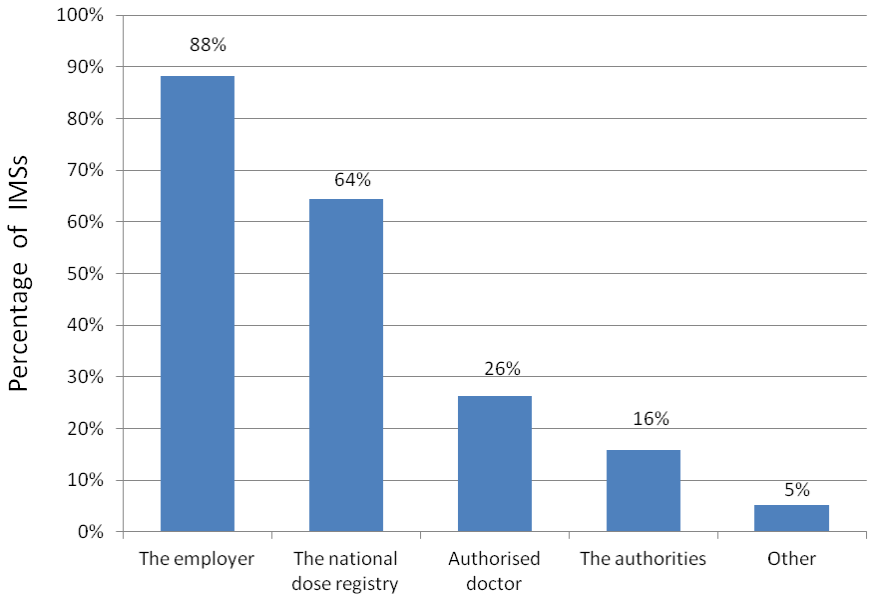

Figure 19. Distribution of the participants' answers on to whom the doses are routinely reported

Main points:

- **IMS results are almost always reported to the undertaking (employer)**
- **two-thirds of IMSs report to the national dose register**
- **other practices vary according to local requirements.**

8.3 U: Content of Reports

Almost all the participants to the survey answered that they report the dose for the monitoring period and 63% answered that they report the cumulative dose for the year to date. Other answers included:

- cumulative dose for the whole time of work ("lifetime").
- dose for the last two monitoring periods.
- the cumulative doses are reported when the dose for the monitoring period exceeds 6 mSv.
- yearly reports with cumulative doses for previous year.
- information on dose accumulated in the last 12 and 60 months is provided through intranet.

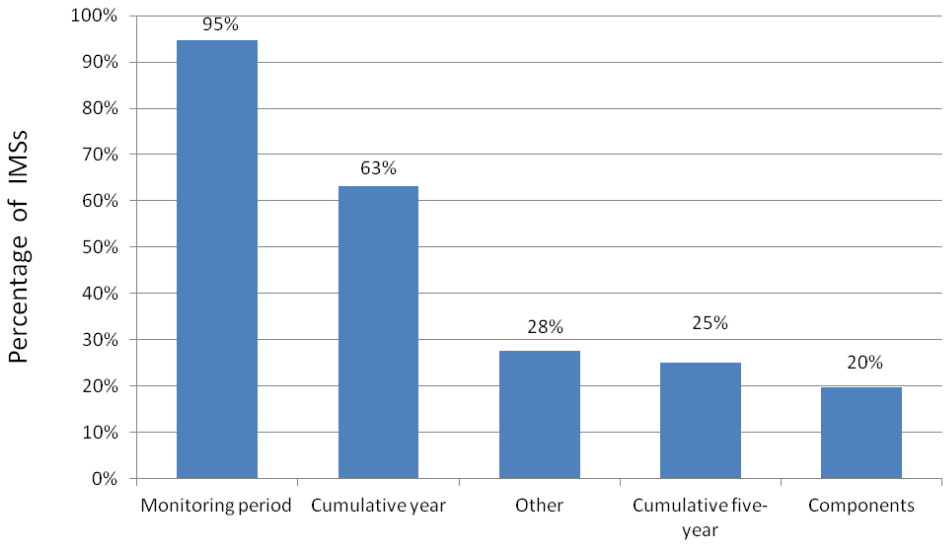

Figure 20. Distribution of the participants' answers on what is contained in the routine dose reports.

Main point:

- **reports from IMS contain the same core information.**

8.4 V: Missing dosemeters

One of the major problems encountered in dosimetry is when a dosimeter is lost or destroyed (see also 4.4 above). Through the survey, the participants were asked to answer who estimates the dose and if the "pro-rata notional dose" is applied in such cases.

A very important result of the survey is that 33% of the participants record **no value** when the dosimeter is destroyed or lost. The same result was shown by the 2003 survey [18], when approximately one third of the services answered that they assign zero, nothing, or give the lost dosimeter a mark. From the total participants to the survey only 9% report the pro-rata notional dose and 43% report the dose estimated by the undertaking, the IMS or the RPE. Most of the participants detailed their answers or specified other cases in the "Other" section of the box. Some of their answers included:

- approved occupational health service or the authorities makes estimate
- for the lost dosemeter no dose value is assigned and for the destroyed ones pro-rata notional dose is applied.
- undertaking provides estimate for Category A, IMS estimates for other categories
- IMS estimate, RPE authorizes. If they don't get an answer from the RPE, then a pro-rata notional dose of 2 mSv by month is applied.
- estimation of the dose if significant dose is expected.
- the dose is estimated with the average dose of former periods.

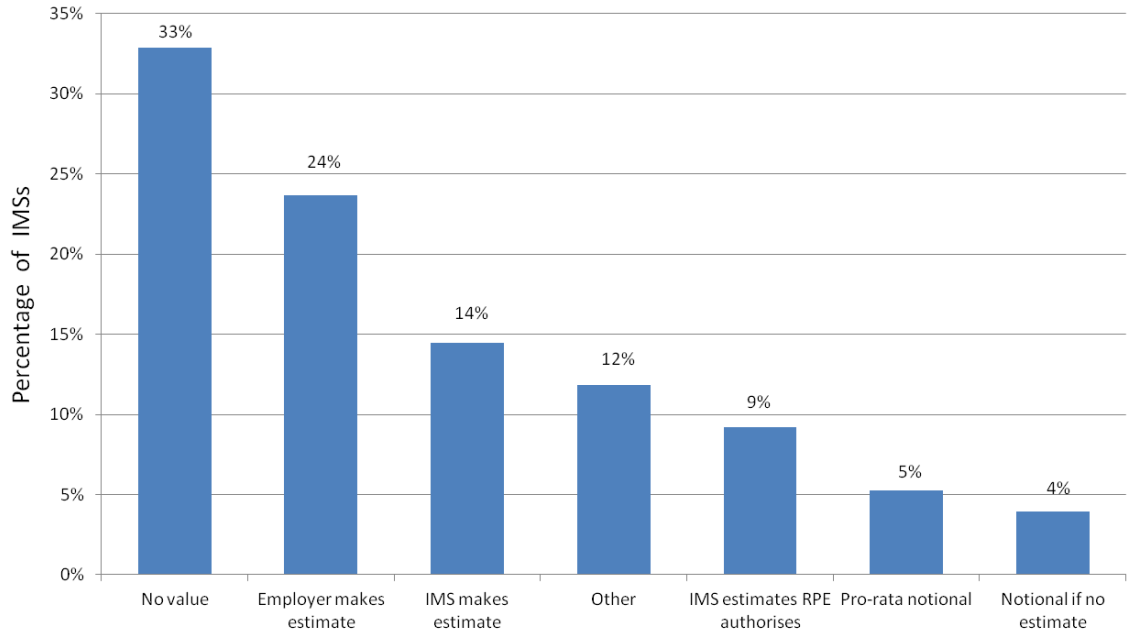

Figure 21. Distribution of the participants' answers on what is done when a dosimeter is lost or destroyed

RP160 [7] does not specifically address the subject of leaving gaps in dose records. However, it is clearly undesirable for a lost, damaged or destroyed dosemeter to be assigned a zero or a "blank", because this could be an incentive for some undertakings or workers to conceal high doses by damaging or losing the dosemeter. Some safeguards are required.

Main point:

- **one third (33%) of responding IMSs said they record no value when a dosemeter is lost or destroyed.**
- **this leaves open the possibility of abuse.**

8.5 W: Dose Quantities

Another issue addressed through the survey is related to the dose quantities reported by the IMS. The 2003 survey allowed the services to choose from $H_p(10)$, $H_p(3)$, $H_p(0.07)$, H_x and K_a. The results showed that 97% of the services reported $H_p(10)$, 80% reported $H_p(0.07)$, 7% reported $H_p(3)$ and only 1% reported K_a.

The current survey included the following possible answers: the personal dose equivalent $H_p(d)$, the effective dose E and the air kerma, K_a. The results show that almost all the services (82%) report the personal dose equivalent and only 17% report the effective dose (the answers in the "Other" box also referred to the personal dose equivalent). Note that those services who report effective dose, E, may be measuring $H_p(10)$ and taking this to be equal to effective dose; it does not necessarily mean that they are measuring (i.e. calibrating in terms of) effective dose.

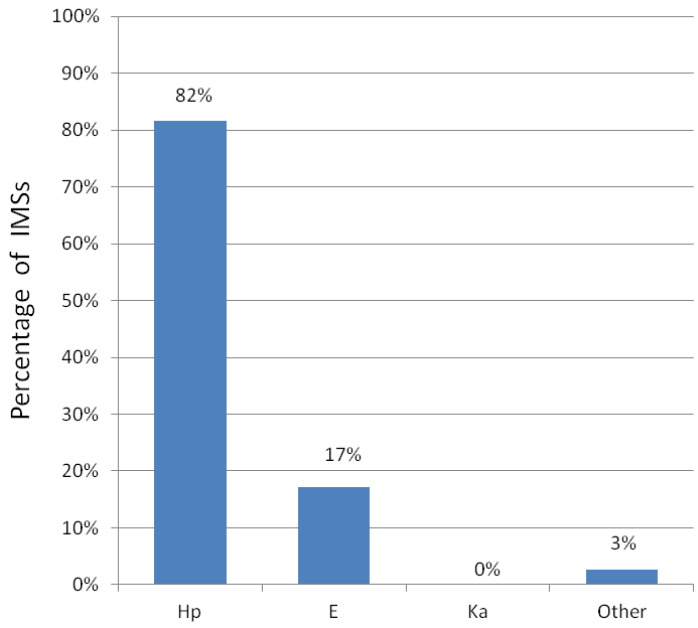

Figure 22. Distribution of the participants' answers on the dose quantities the dose values are reported

Main point:

- **Almost all IMSs report $H_p(d)$, or E and H_T.**

8.6 X: Personal IDs

It is very important to establish a link between a dose value assessed by reading a dosimeter and the corresponding exposed worker. RP160 [7] recommends that a monitored worker's record should be uniquely identified using both the worker's ID number and the undertaking ID code.

The survey results show that 50% of the participants use the national unique ID of the worker and 43% use a unique ID issued by the IMS. Few of the participants (3%) reported that they use both a national unique ID and a unique ID issued by the IMS. Other participants reported that they identify the exposed worker by using:

- the worker's name and a unique ID for the dosimeter
- a unique ID issued by the national dose registry
- a non-unique ID issued by service
- unique ID issued by undertaking
- the worker's name and personal number
- the national health insurance ID
- a special algorithm from the national dose registry

The results of the 2003 survey showed a higher percentage of the participants who use the national ID (59%) and a lower percentage of the participants who use the service specific ID (28%).

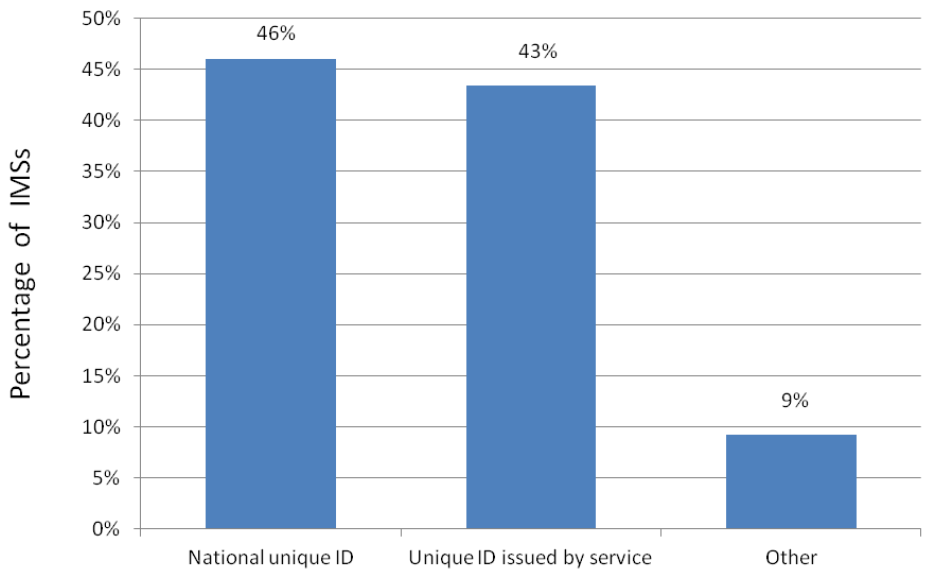

Figure 23. Distribution of the participants' answers on how the workers are identified for dose reporting and recording

9 Measurement Uncertainties, Low-Dose Measurements and Method of Reporting

9.1 Y: Measurement uncertainty

9.1.1 General

In general there is a large uncertainty associated with dose measurements. Although the standard deviation in repeated measurements under identical irradiation conditions can be as little as a few percent, the energy and angular response characteristics in general introduce uncertainties of between 10 and 20% [35]. Also, the uncertainties associated with very low doses will generally be much larger. If the contribution of the natural background, which has carries its own uncertainty, is subtracted, the standard uncertainty in these very low doses will be between 10 and 100 µSv. Whereas most services have assessed the uncertainty in their measurements, only a few reported having used one of the international standards on the expression of uncertainty in measurements, the ISO-GUM [36].

9.1.2 How is Uncertainty Assessed?

IMSs were asked about their approach to evaluating measurement uncertainty. Measurement uncertainty can become very important where doses approach or exceed legal dose limits, while testing laboratories that comply with ISO 17025 [19] must have a procedure for evaluating uncertainty. The results are shown in Figure 24, where the numbers of services using a JCGM-100 [37]/ ISO GUM [36] approach and using their own approach are about equal. Most encouraging is that 96% of services say that they do assess measurement uncertainty – an increase from the 83% reported in 2003.

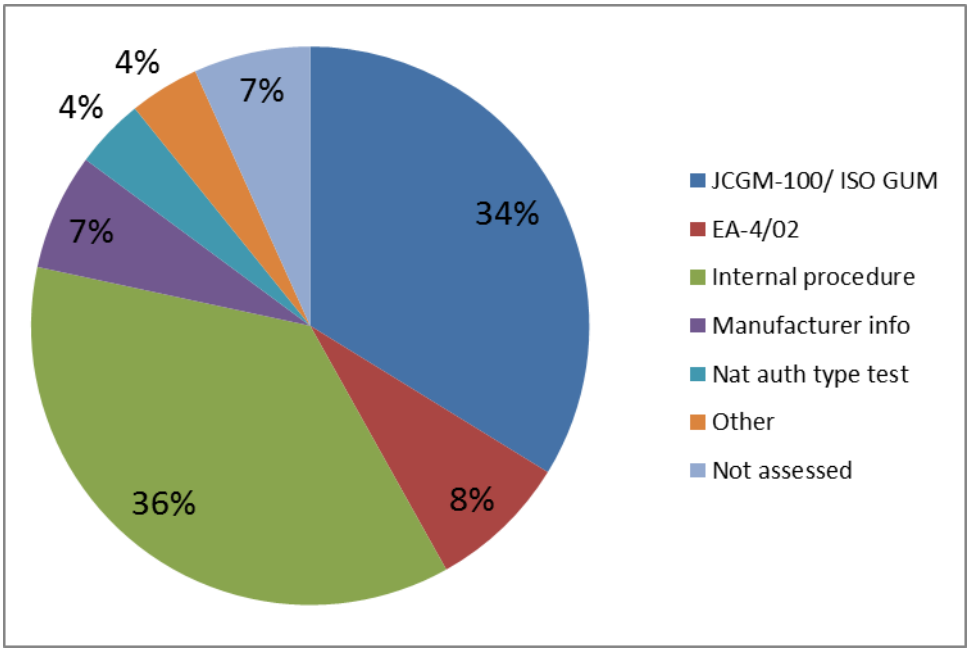

Figure 24. Summary of responses on method of measurement uncertainty.

Main point

- **almost all responding IMSs (96%) report that they assess measurement uncertainty.**

9.1.3 How is Uncertainty Reported?

ISO 17025 [19] requires that a statement on the estimated uncertainty of measurement is included in dose reports when:

- it is relevant to the validity or application of the test results
- when a customer's instruction so requires
- when the uncertainty affects compliance to a specification limit.

For an IMS, the last of these could apply at any time. Therefore it is important that some indication of measurement uncertainty be given to the customer.

The results are shown in Figure 25. Only 9% show the uncertainty for every dose reported, while over 21% rely on generic information (leaflets or web site), some with a general statement in the reports. More than a quarter of IMSs do not report uncertainty at all.

IMSs were not asked about the reasons behind their approach to reporting uncertainty; however, one consideration might be the attitudes of customers (undertakings). If the concept of measurement uncertainty is poorly understood, or if customers are unhappy without definitive conclusions, there might be a temptation to avoid the question. Nevertheless, it is best practice to report the uncertainty, or at least to make it clearly and openly available.

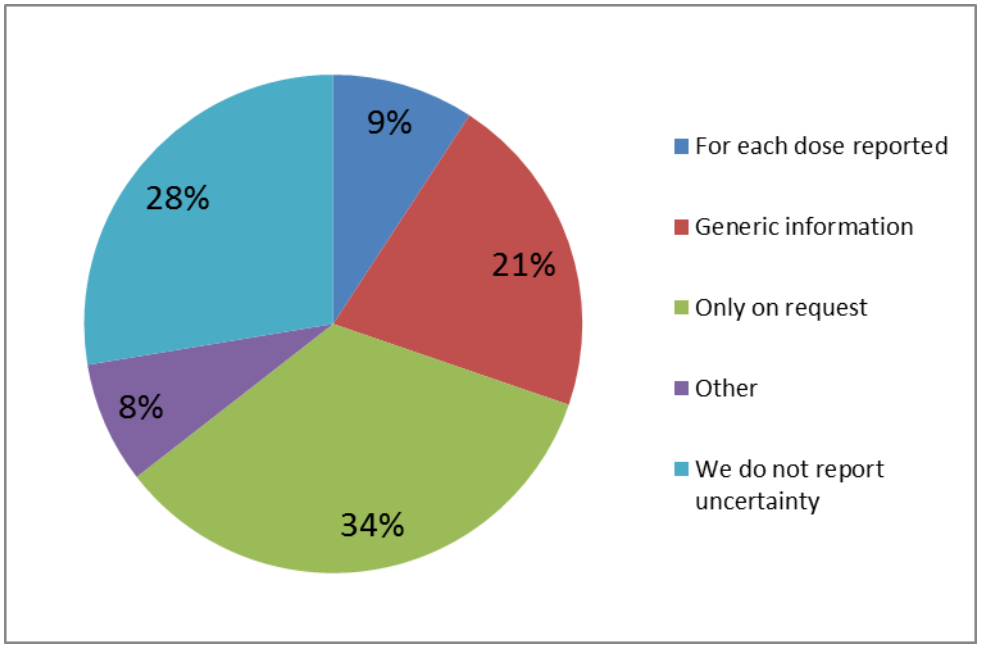

Figure 25. Approaches to reporting uncertainty

Main points

- **most IMSs do not quote the measurement uncertainty for every dose reported.**
- **there is a preference for generic information sheets or information on request.**
- **over a quarter of IMSs do not report uncertainty at all.**

9.1.4 Comparison of Assessed Uncertainties

The 2012 survey went further than that of 2003 [18] in asking IMSs to report their estimate of total relative uncertainty for a very specific set of conditions. The conditions were:

a. whole-body dosemeters only
b. photon/electron dosemeters only
c. 1-month issue period
d. received dose of 1 mSv
e. coverage factor $k = 1$

Conditions (c) and (d) were specified in order to reduce the importance of low-dose and high-dose corrections, and to give an indication of typical measurement uncertainty. The question specifically asked for ALL sources of uncertainty to be taken into account.

Given the similar performance of most common methods of dosimetry, and given the dominance of the energy and angle dependence of response in the overall uncertainty [7, 35], a broadly similar set of answers was expected. 27 IMSs (36%) did not answer the question. The results for those who did are shown in Figure 26.

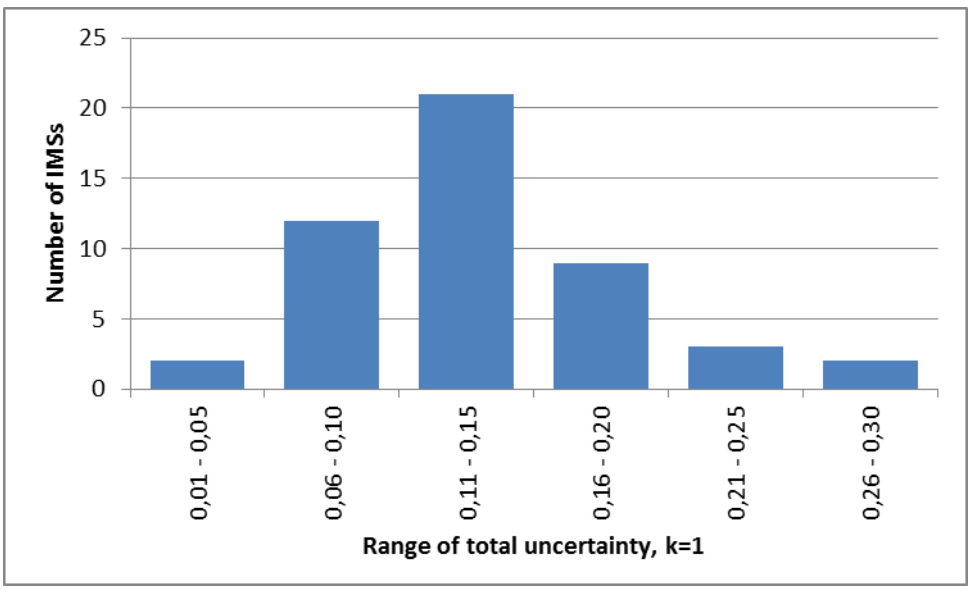

Figure 26: Assessments of total relative uncertainty, in a standardised condition (see text), for those IMSs responding to the question.

This broad agreement was observed, although there were some outliers. Of the respondents, most IMSs (43%) reported relative uncertainty values in the range 0,11 – 0,15, while almost all (86%) reported values between 0,06 and 0,20. Some IMSs reported very small uncertainties, with the lowest reported by any service being 0,03, while others reported much larger values, up to 0,30. In practice, uncertainties like these are most unlikely.

The **very low values** quoted could be for calibration conditions, where the radiation field is known, so that the contributions from energy and angle dependence of response are removed. Even so, a relative uncertainty of 0,03 seems to be an underestimate. Note that RP160 [7] states that "a distinction should be recognized between the accuracy of a measurement with a dosemeter under laboratory conditions, in a well-known radiation field, and a measurement in the workplace" (Section 6.5). Uncertainties in practical measurements in the workplace will be markedly greater.

Meanwhile, the **very high values** could well arise from a misreading of the question. IMSs are used to quoting results with a coverage factor of 2, or close to 2, i.e. considering confidence levels around 95%, for example in comparing results with the "trumpet curves" [38]. Some IMSs may have mistakenly submitted such estimates instead of the k=1 case requested.

Main points:

- **Typical relative uncertainties, for whole-body photon/electron dosemeters with a coverage interval of k=1, lie in the range 0,11 to 0,15.**
- **Estimates that are very much lower should be re-examined to ensure that all sources of uncertainty have been taken into account.**
- **More than a third of IMSs did not provide an estimate.**

9.2 Z: Natural background

IMSs were asked what method they used for compensating for natural background. The distribution of answers is shown in Figure 27. IMSs were allowed to return more than one answer, if they operated more than one method (e.g. because they use more than one kind of dosemeter). From the 76 IMSs, 120 answers were received.

Note also that, for any IMS, the method of natural background compensation is partly determined by the dosimetry technique. For example, whilst passive dosemeters accumulate background all the time, active dosemeters that can be read out at the start and end of each shift only do so during that shift. Because active dosemeters can be reset, or powered off, they do not accumulate dose whilst not in use. In these cases the accrued background may be negligible. Or again, photographic film dosemeters normally rely on batch calibration arrangements that include keeping a stock of unexposed films, some of which are processed whenever other films from that batch are processed. These unexposed films, sometimes called "fog" films, take into account the total of the intrinsic dosemeter background plus the accrued natural background.

A further factor in determining background compensation practice could be national custom or requirements.

The responses shown as "other" included the following.

- Background determined per customer, based on statistical analyses of measurement results of many years (not used dosemeters).
- Measurement at IMS.
- Control per each measurement period.

Five of the responses (4%) were "not subtracted". Of these, two referred to TLD systems, two to film, and one to APDs.

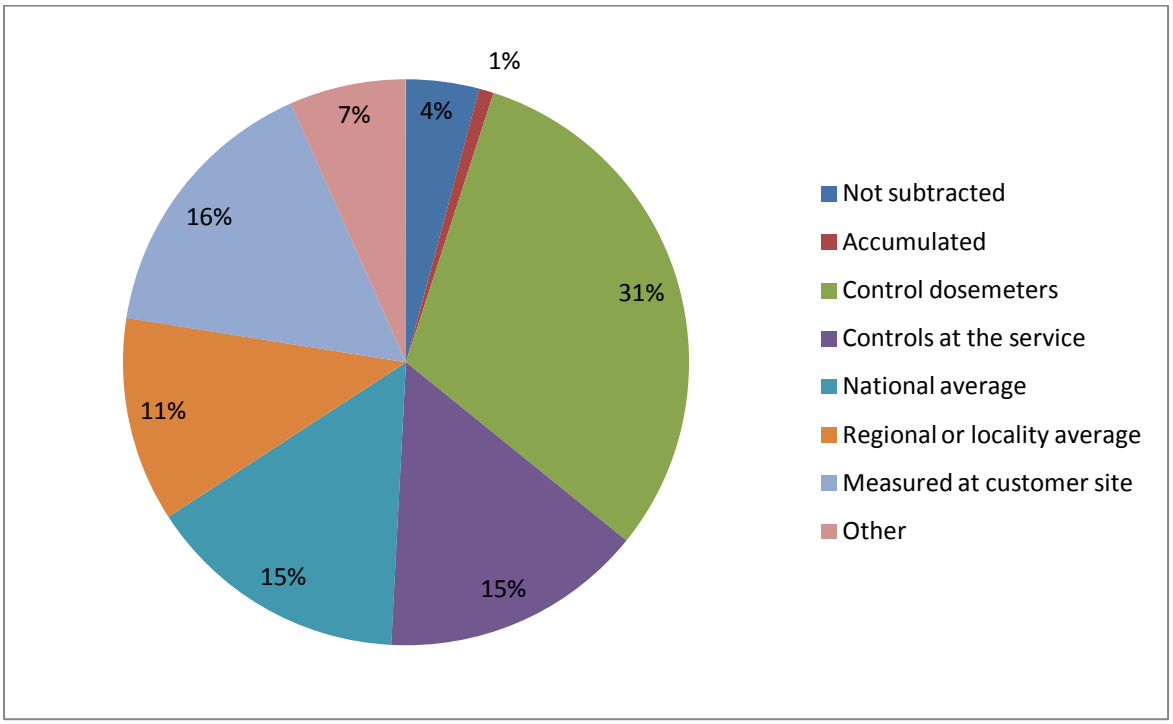

Figure 27. Summary of responses on how IMSs deal with natural background.

Main points:

- **there is a wide range of approaches to dealing with natural background.**
- **most common is the use of shipped control dosemeters (almost one third of IMSs).**
- **practice can depend on the method of dosimetry or national requirements.**

9.3 AA: Threshold doses

ICRP [39] have defined the concept of a *Recording Level*, to allow for the exclusion of trivial results. For effective dose, this should be set no lower than 1 mSv per annum, according to the length of monitoring period (so about 0.083 mSv for a calendar month). In practice, however, IMSs have tended not to define a formal recording level, but instead to allow their circumstances to determine their policy on reporting of doses (reporting level) as or near detection limits. These local circumstances can include:

- national requirements.
- limitations of the method used.
- customer expectations.
- competing methods/ IMSs.

E.g. on the last of these, the increasing use of APDs with very low (microsievert-level) detection limits might increase pressure on IMSs who use passive dosemeters to lower their reporting level (i.e. the smallest non-zero dose that is routinely reported).

In the survey, IMSs were asked what had decided their choice of their reporting level, and what the value of that limit was for their whole-body photon dosemeter. They were further asked how these doses were treated in records of cumulative dose.

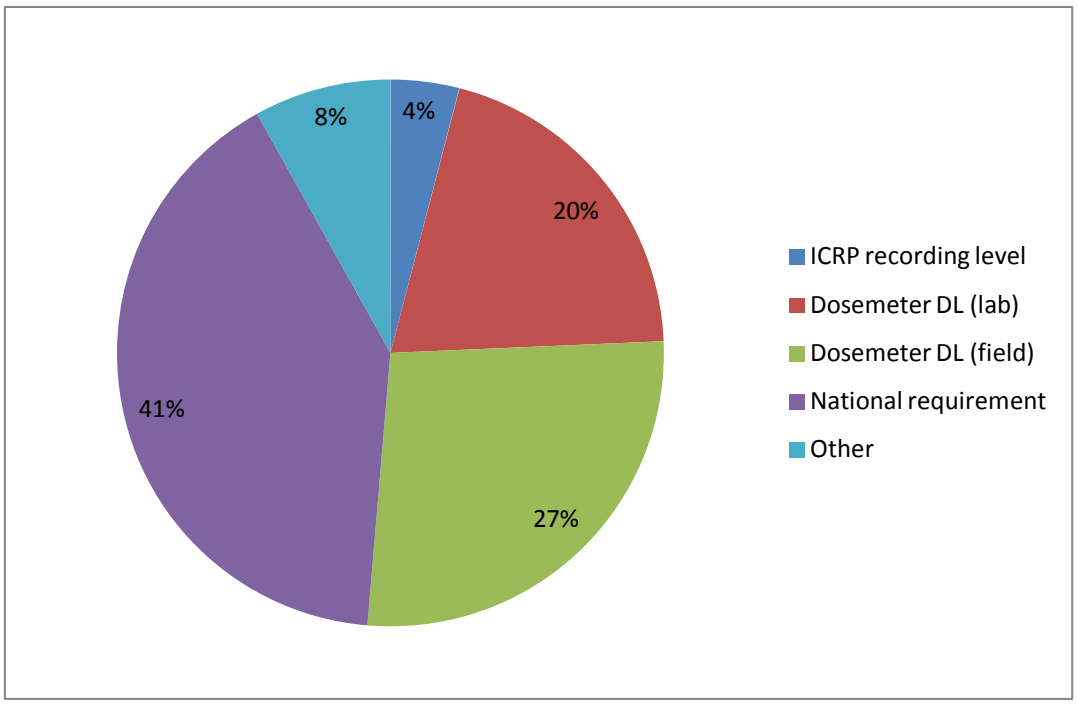

Figure 28. Summary of bases for reporting thresholds. DL = Detection Limit.

As can be seen from Figure 28, only a few IMSs have selected their reporting limit based on the ICRP recording level. The commonest determinant is national requirement (41%), with most of the remainder determined by dosemeter limitations, either in the field (27%) or the laboratory (20%). Amongst the "other" responses were:

- A variable reporting level, dependent upon the characteristics of the film batch.
- The number of digits in dose report – applying a *de facto* rounding to all results.

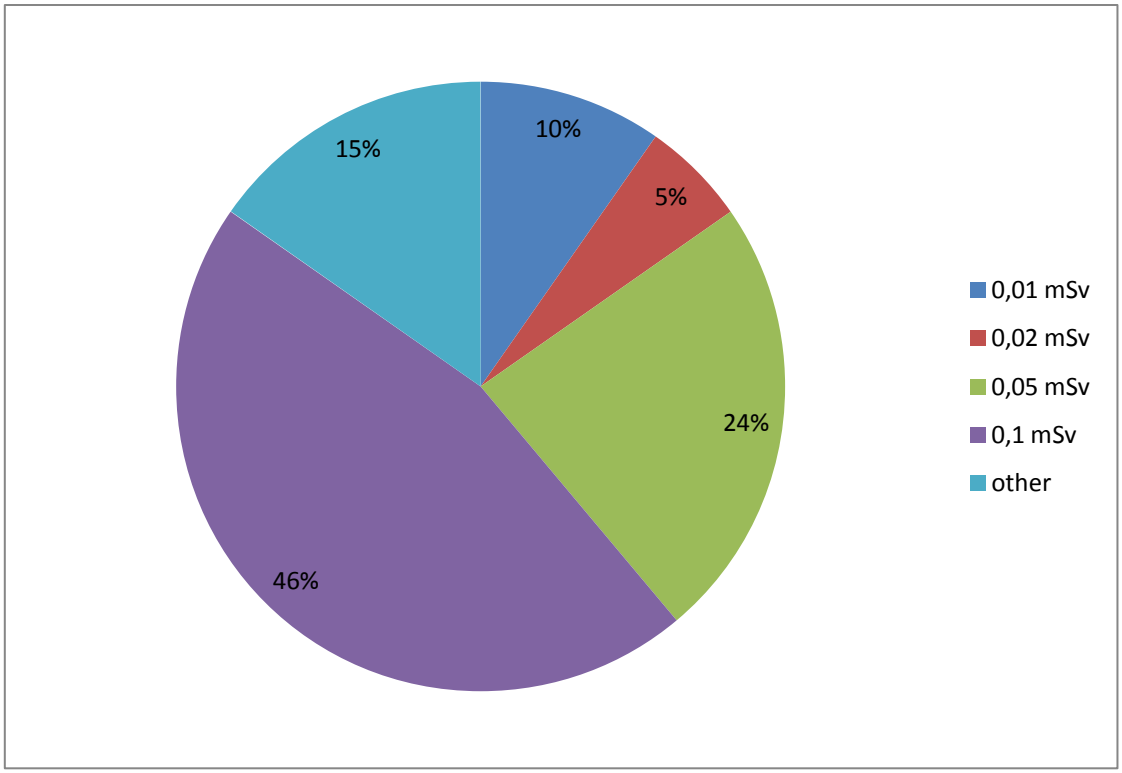

Figure 29. Summary of values for reporting thresholds

The commonest reporting levels were 0,10 (46%) and 0,05 mSv (24%). The smallest was 1 µSv (APD) and the largest 1 mSv.

There was a range of responses for the question about how sub-threshold doses were treated in dose records. 74% of IMSs (a similar fraction to 2003[18]) treated these doses as zero. For the remainder:

- one service records sub-threshold doses as "MDL" (but did not say how these were treated in summations)
- several services treat sub-threshold doses as a fixed value in summations (mostly 0,05 mSv, but ranging from 0,015 to 0,2 mSv)
- some IMSs said that they report "whatever the dosemeter measures"
- some IMSs are goverened by national requirements which require them to treat all doses below a given value (e.g. 0,075 mSv) as zero – even if the dosemeter can measure lower doses than this.

Main points:

- **Practice on threshold doses varies.**
- **Some practices are governed by national requirements.**
- **Commonest reporting level is 0,10 mSv.**
- **Three-quarters of IMSs treat doses below the reporting level as zero in dose summations.**

9.4 AB: Reporting method

The 2012 survey also sought to discover the popularity of electronic means of dose reporting. IMSs were asked how they reported doses – see Figure 30 for the options. Multiple answers were available, so that 28 services said they use two of the three methods, while a further ten said they use all three.

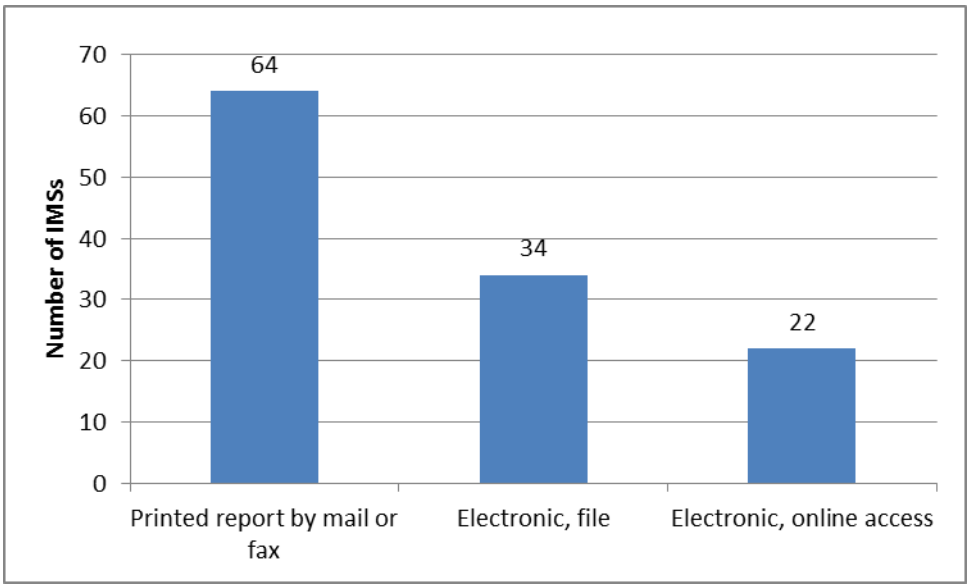

Figure 30. Methods of dose reporting

The 2003 survey did not ask about how the dose reports were sent to customers, but it is safe to assume that there was greater use of electronic methods in 2012. Paper-based dose reports still predominate, with 84% of IMSs still using them; but 61% of services are using some form of electronic transmission. Further points were:

- Two IMSs misinterpreted the word "mail" as meaning electronic mail, when in fact it was intended to mean hard-copy postal services.
- One IMS makes results available via an intranet, rather than the world wide web.

Main points

- **Most IMSs send reports by "hard copy" by regular post of fax.**
- **About half report electronically.**
- **Over a quarter provide online access.**

10 Causes of Error

IMSs were asked to allocate a score to each source, or cause, of error. The score was a measure of both severity and frequency, and therefore was indicative of how much trouble each cause of error gave to the IMS. For example, a severe error that occurs very infrequently could, if wished, be given a lower score than a trivial error that occurs frequently. The overall scores given in the sections below are, for each source of error, the average of the scores given by the IMS.

IMSs were first asked about the "top 5" causes of error that did *not* depend on dosemeter type, e.g. physical damage, which can happen to any type of dosemeter. These scores were rated from 1 (least severe) to 5 (most severe).

They were then asked about the "top 3" causes that were specific to the types of dosemeter (i.e. that did depend on dosemeter type) that were used in the IMS. Scores were rated from 1 to 3. Note: the severity of the scoring, as indicated in the sections by dosemeter type, is relative within the dosemeter type. A source of error that is important for one type of dosemeter could, in practice, give fewer problems than a source that is less important for another type. In other words, care is needed in comparing sources of error between systems.

In the discussions below, more detail is presented for the methods (film and TLD) that are used most widely, than for the other methods, used by small numbers of IMSs.

10.1 AC: Causes Common to All Types

Figure 31 presents the weighted scores, out of 5, for the various types of error. For example, a cause of error that was scored as most significant (5) by every IMS would yield a weighted score of 5. From the figure it is apparent that "Wrong wearing position" and "Significant irradiation when not being worn" are the most troublesome causes of error, either in terms of frequency or severity.

Most of these causes of error arise from the treatment of the dosemeter during use, or in transit; in other words, when the dosemeter is outside the control of the IMS. These are "external" factors. Some, however, arise when the dosemeter is within the control of the IMS. These are classed as "internal" factors and are shown in red in the figure.

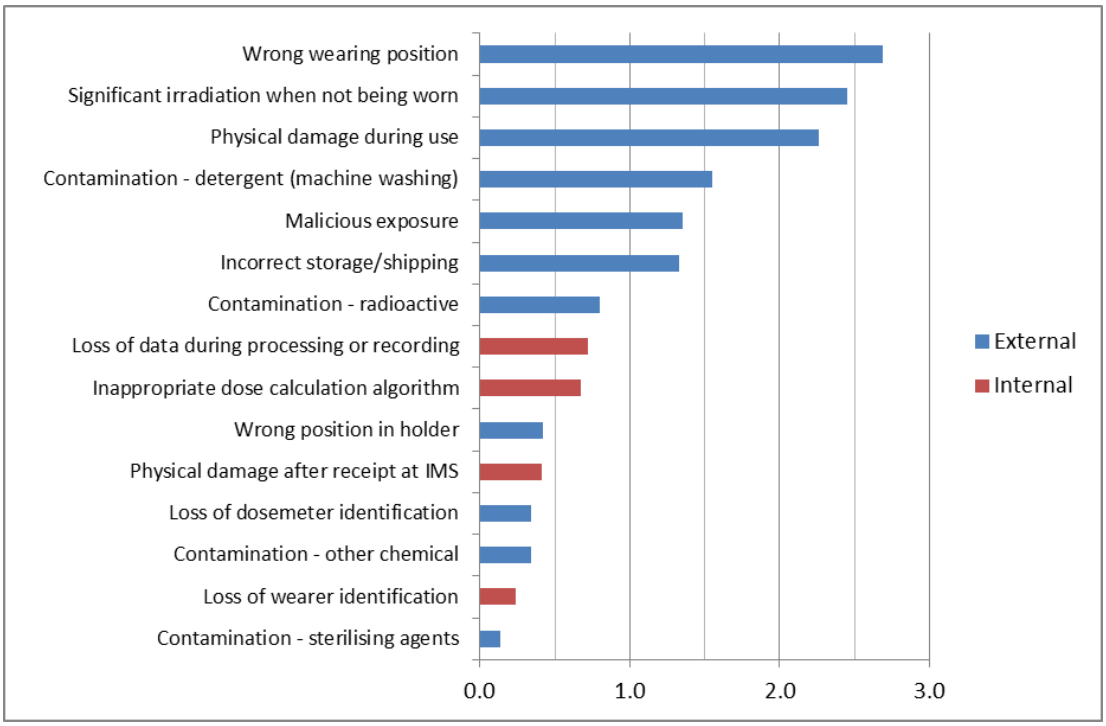

Figure 31. Most important sources of error common to all dosemeter types. Those with blue bars are "external" – i.e. beyond the control of the IMS. Those in red are "internal", i.e. within the control of the IMS.

In addition to the errors listed, IMSs were invited to mention other causes of error. Responses in this "Other" category included "incorrect background subtraction" (2 mentions) and "dosemeter never returned" (2 mentions).

An interesting feature of the results is the prominence of "malicious exposure". This cause of error was new to the 2012 survey and includes not only the occasional deliberate exposing of another worker's dosemeter in order to cause trouble, but also the exposing of a worker's own dosemeter in order to give the impression of higher routine doses. In some countries this can lead to the worker's "exposed" status – and the enhanced pay that goes with it – being maintained.

In comparison with the 2003 survey, the 2012 survey shares some of the most troublesome sources of error. For instance, "significant irradiation when not being worn" gave high ratings in both. However, comparison of the top five causes in the two surveys reveals some changes.

Table 5. Top five causes of error in 2003 and 2012 surveys.

2003	2012
Loss or damage during processing	Wrong wearing position
Significant irradiation when not worn	Significant irradiation when not being worn
Defective dosemeter	Physical damage during use
Radioactive contamination	Contamination - detergent (machine washing)
False assignment of dosemeter	Malicious exposure

"Loss or damage during processing" has diminished in importance, which is encouraging. This could be because IMSs have better QC. Likewise, "False assignment of the dosemeter / Loss of dosemeter identification", and "defective dosemeter" have become less important, which again could indicate improved QC. Conversely, "wrong wearing position" has become more important; note here that not all IMSs are able to collect evidence about correct use, so it may be that the change is due to IMSs becoming more aware of the problem.

10.2 Causes, by Type of Dosemeter

10.2.1 AD: APD (Active Personal Dosemeters)

Only a few IMSs (3) use APDs for legal dosimetry, with about 14 000 workers covered. Note that APDs may be read many times per month, and are typically used for just one shift (day). Hence, figures for the number of dosemeter issues per year are not comparable to those for passive dosemeters.

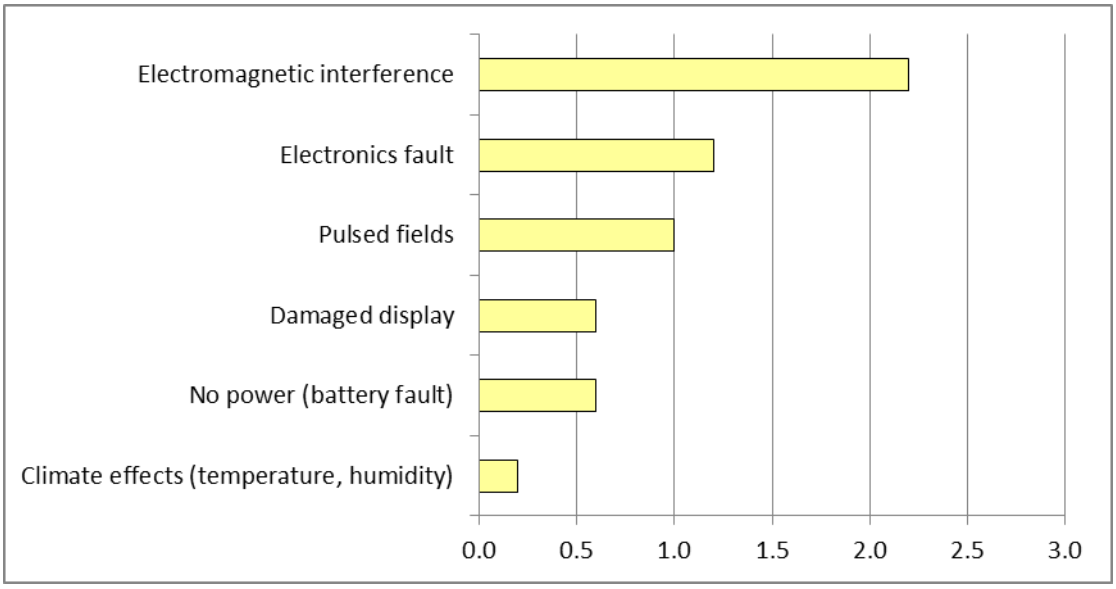

Figure 32. Most important sources of error for APDs (Active Personal Dosemeters)

The most important source of error or increased uncertainty seems to be **electromagnetic interference**. Also electronic faults are affecting the accuracy of the measurements as well as lack of power (e.g. battery faults).

For two services, pulsed fields are important source of error and for one climate effects cause an increase of uncertainty.

10.2.2 AE: DIS (Direct Ion Storage)

As well as APDs, only a few IMSs (3) use DIS dosemeters, covering about 12 000 workers. Note that DIS dosemeters can be issued permanently to workers, with the worker presenting the dosemeter at intervals for read-out. So, as with APDs, figures for the number of dosemeter issues per year are less meaningful than for passive dosemeters.

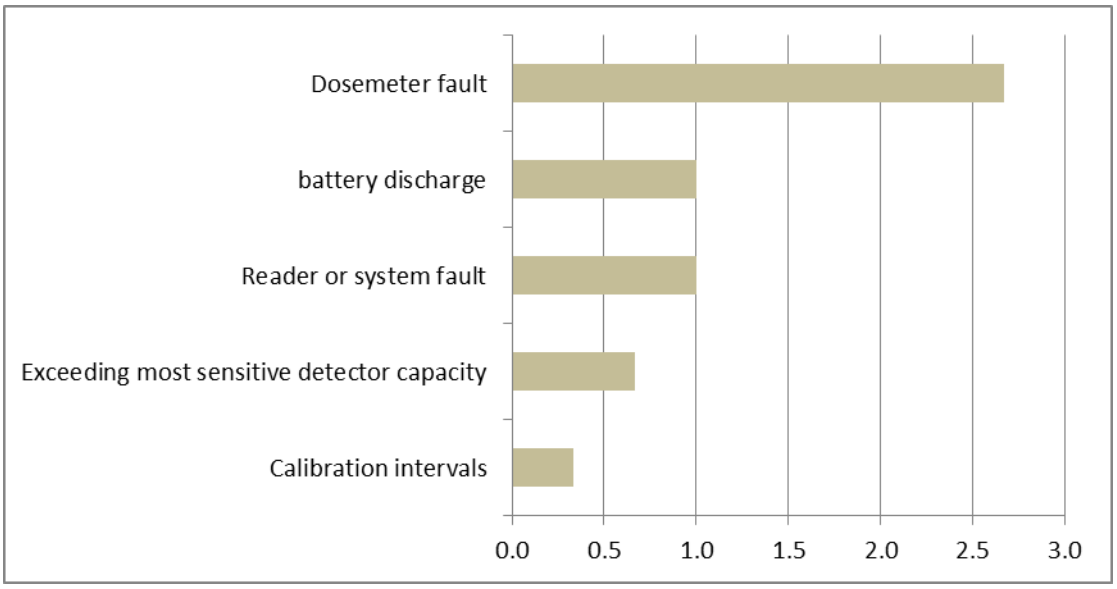

Figure 33. Most important sources of error for DIS (Direct Ion Storage) dosemeters.

The most important source of error or increased uncertainty is **dosemeter faults**.

Other important source for errors are reader or system faults, battery discharge, exceeding most sensitive detector capacity and calibration intervals.

10.2.3 AF: Film (Photographic Film)

From the total of 76 participants to the survey, 15 IMS answered that they are using the photographic dosimetry system and they provided information for this section.

A summary of the distribution of the participants' answers, and the ranking received by every source of error or increased uncertainty, is presented in Figure 34. The other source of error reported by one of the 15 participants is "irradiation during transit".

Figure 35 presents the importance of every source of error in photographic dosimetry. For every source of error, the number of answers as 'the most important source' was multiplied by 3, as the second important source was multiplied by 2 and the number of answers as the third important source was multiplied by 1. The results show that the most important source of error is light exposure during use (film opened), followed by incorrect energy correction and climate effects (temperature, humidity, etc.).

The results of the 2003 survey also showed that the light exposure of the dosimeter opened by the customers is the biggest problem for the photographic dosimetry services. The next most important source of error was the light exposure of the film during processing. In the 2012 survey, this type of error was not considered very important (only one photographic dosimetry service ranked it as TOP1 source of error and another one ranked it as TOP2) and the incorrect energy correction and climate effects were considered more important. These two types of sources of error were not included in the 2003 survey.

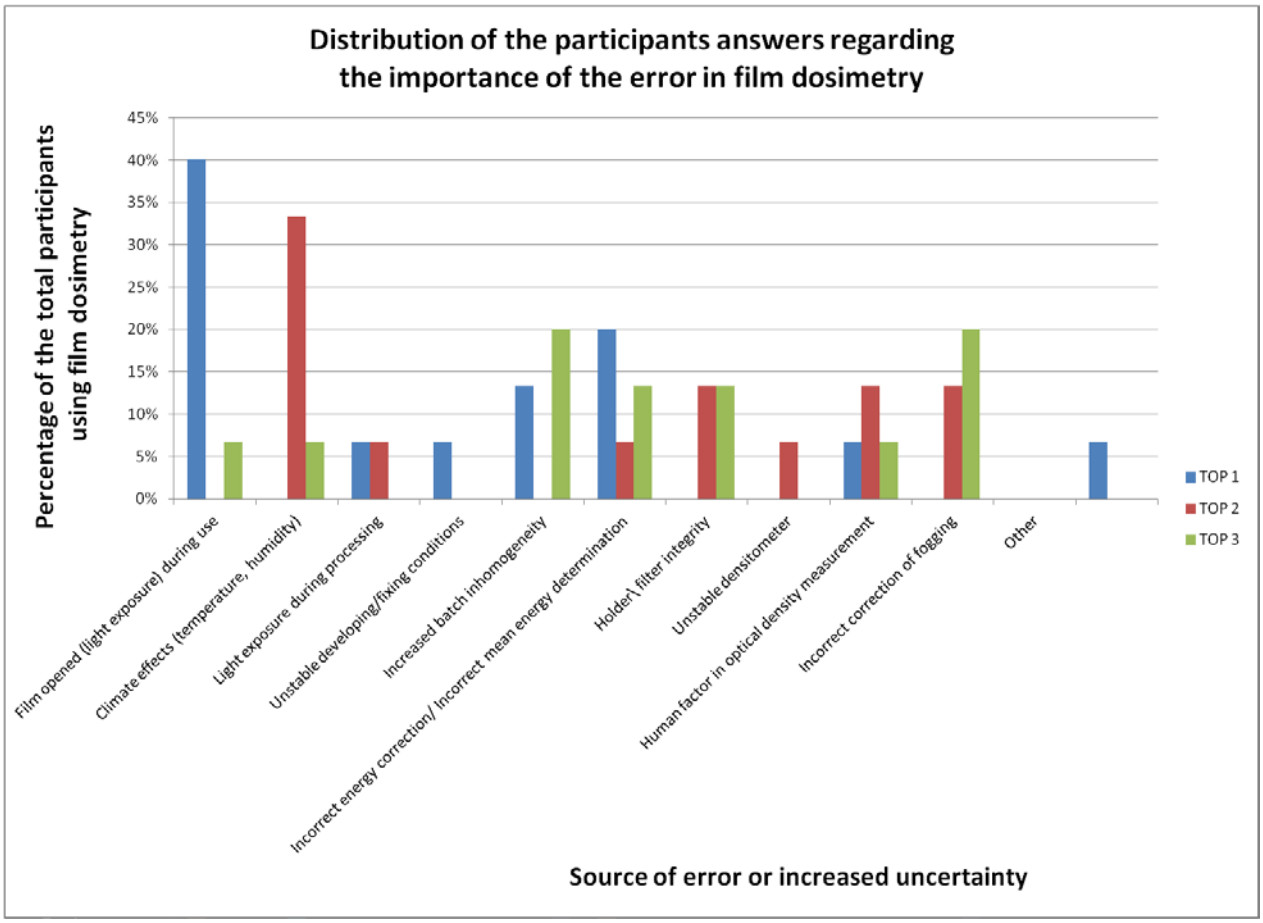

Figure 34. Distribution of the participants' answers on the most important sources of error or increased uncertainty in film dosimetry

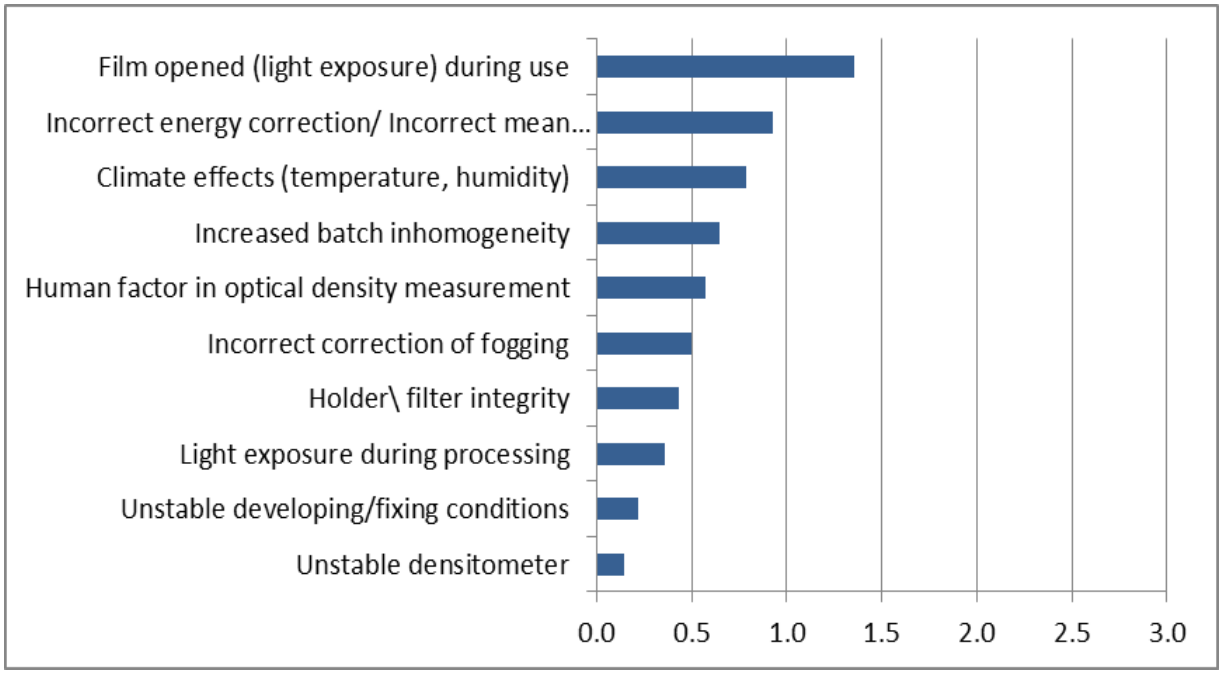

Figure 35. Importance of the source of error, photographic film dosemeters.

10.2.4 AG: OSL (Optically-Stimulated Luminescence)

Very few IMSs (3) use OSL, though these account for 3.2% of the total dosemeters issued per year by respondents. This should be borne in mind when interpreting the following results.

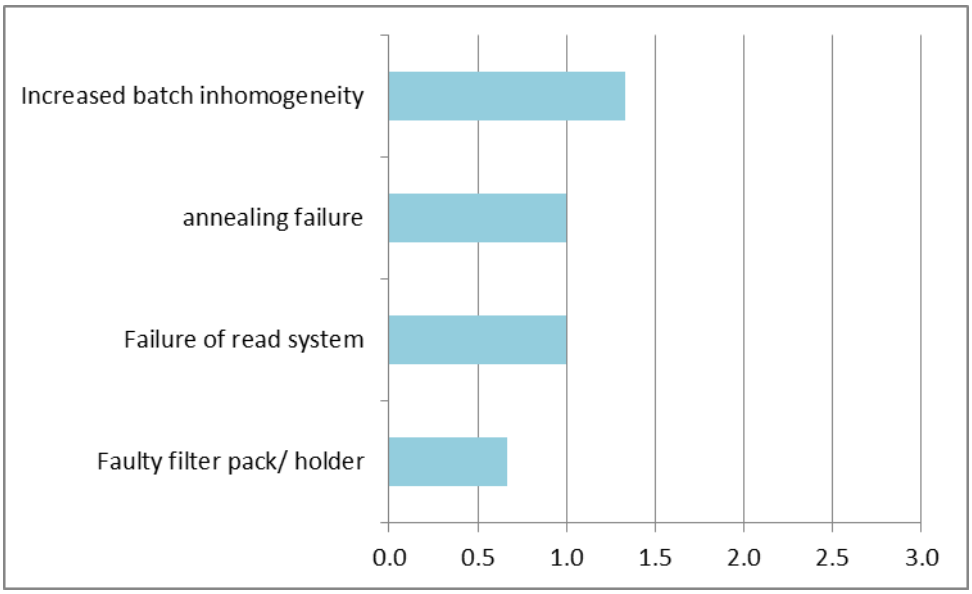

Figure 36. Most important sources of error for OSL (Optically-Stimulated Luminescence) dosemeters.

"Increased batch inhomogeneity" was the most significant source of error. Note that, as with TLD, OSL methods differ in their details, most importantly in the materials used.

10.2.5 AH: RPL (Radio-photo Luminescence – "Glass" Dosemeters)

Similarly, very few IMSs (3) use RPL, but because it is used by some large IMSs, the method accounts for 14% of the total dosemeters issued per year by respondents.

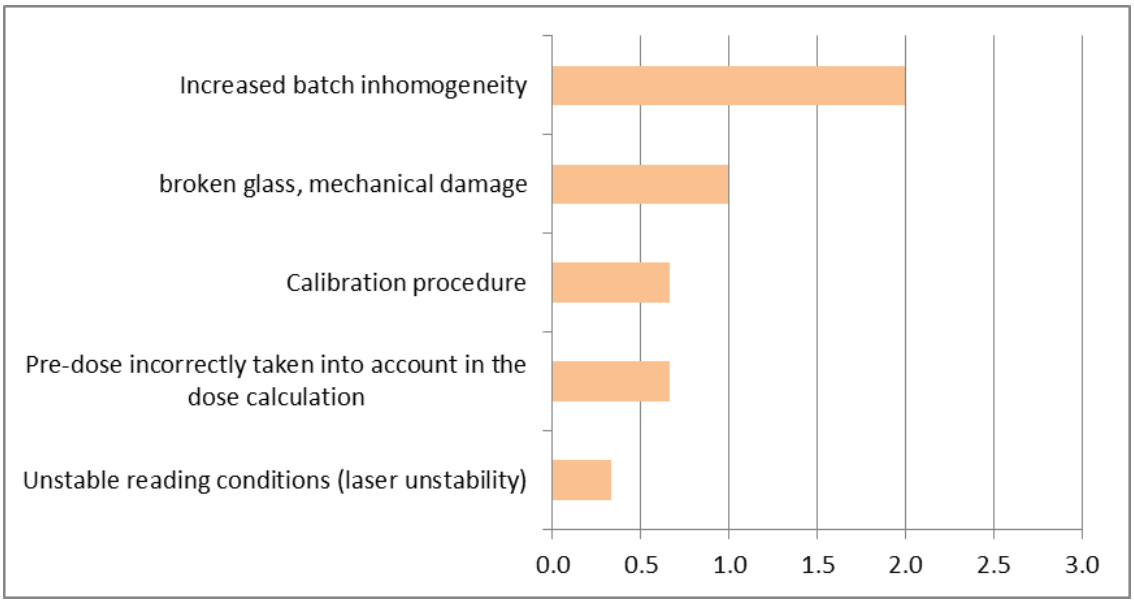

Figure 37. Most important sources of error for RPL (Radio-Photo Luminescence) dosemeters

Here, "increased batch homogeneity" and "broken glass/ mechanical damage" are the most significant source of error.

10.2.7 AI: TLD (Thermoluminescence Dosemeters)

Participants' responses are summarised in Figures 37 and 38. Following the practice of the 2003 survey, "irregular glow curve" was included as a possible source of error, although the real question is perhaps, what causes the irregular glow curve: damage to the TLD elements? Chemical contamination? Reader errors? This question is made the more relevant because, in the present study, "irregular glow curve" emerges as the most important source of error. In the 2003 survey, which broke the assessment of error causes into severity and frequency, this particular cause was the most frequent, but had only moderate severity.

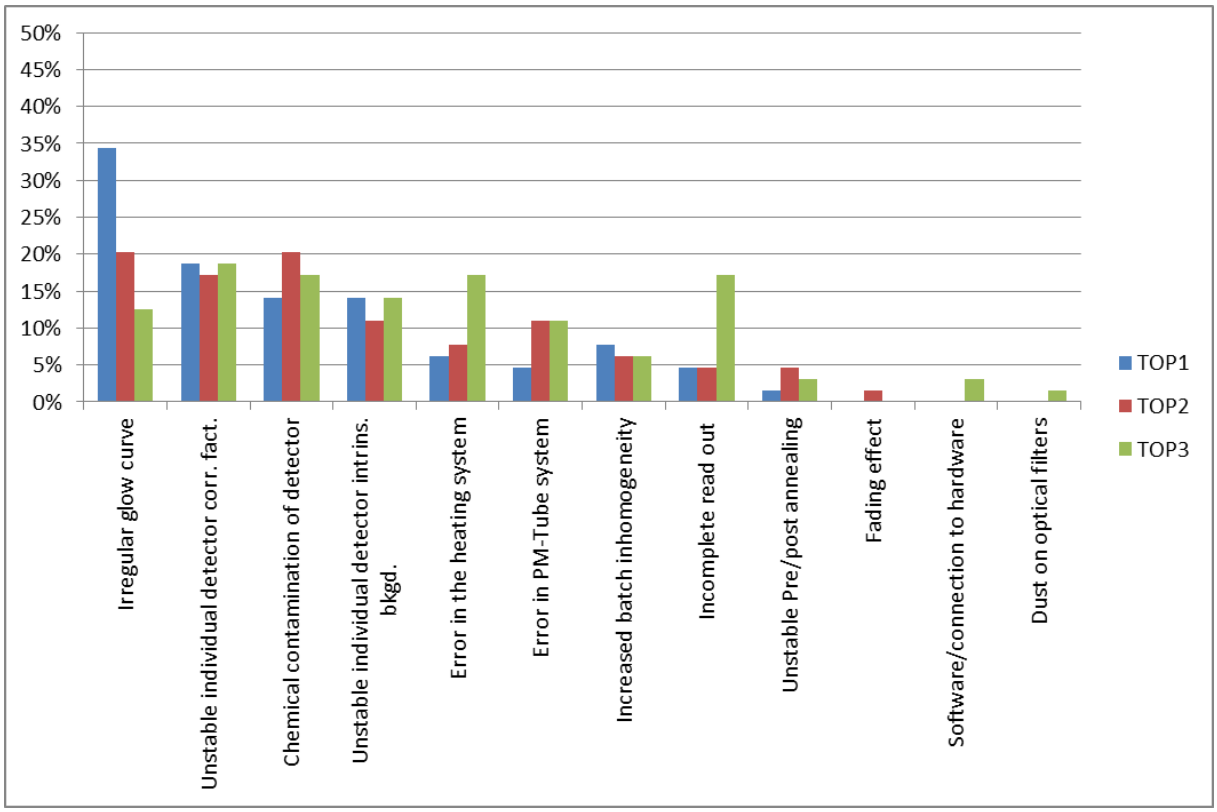

Figure 38. Distribution of the participants' answers on the most important sources of error or increased uncertainty in TL dosimetry

The other most troublesome sources of error in TLDs were chemical contamination (also ranked highly in 2003) and detector instability, both in terms of sensitivity and intrinsic background. In the latter case, care needs to be taken in determining whether it is the detectors themselves that are unstable, or the measuring system. Good routine QC will clarify this.

In the 2003 survey, errors in the TLD readers (heating system or photomultiplier tube system) were evaluated as having high impact but low probability; and in the combined approach used in the present survey, they appear with moderate overall importance.

These causes of error will also be amongst those relevant to the use of albedo neutron dosemeters.

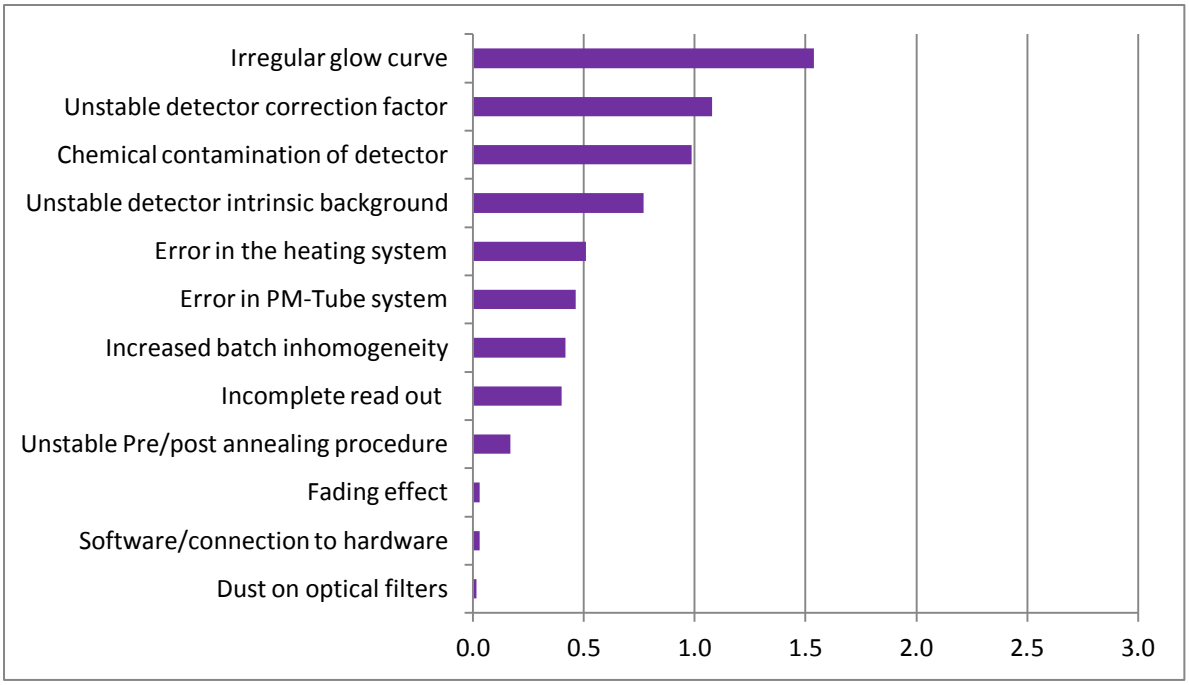

Figure 39. Most important sources of error for thermoluminescence dosemeters (TLDs)

10.2.8 AJ: Neutron Track Etch Dosemeters

12 IMSs use track etch to measure neutron doses, 9 of whom provided information for this section. The most significant sources of error are (i) the well-known variability of material quality, which influences two of the causes, and (ii) unstable etching conditions.

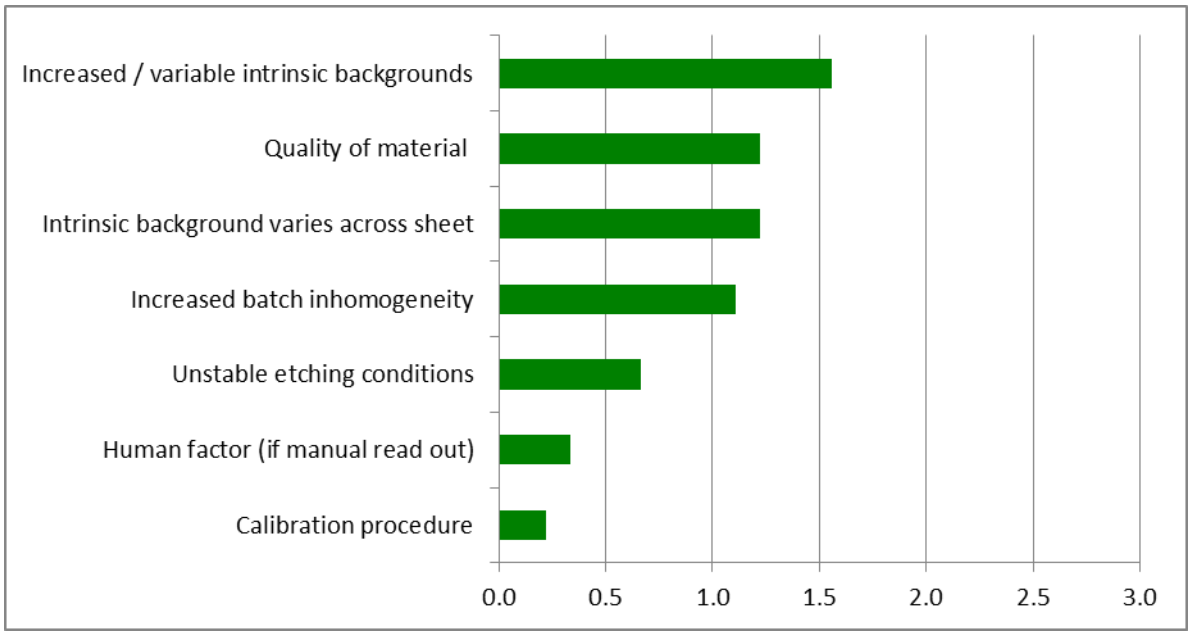

Figure 40. Most important sources of error for neutron track etch dosemeters.

10.2.9 AK: Neutron Bubble Dosemeters

No services reported using bubble dosemeters for routine neutron dose assessment.

10.2.10 Albedo Dosemeters

17 services reported measuring neutron doses using TLDs as albedo dosemeters. Whilst some of the sources of error for TLD albedo dosemeters will be the same as for TLDs in general (see AI), unfortunately the survey did not ask for other, specific causes of error for this method. To seek this information, IMSs that reported using albedo dosimetry were approached separately and asked two questions, shown below together with a summary of the answers.

Q1. What do you regard as the most important sources of error in albedo dosimetry?

- There was unanimous agreement that the **correction for neutron energy/ energy dependence of response** was an imporant source of error.
- Other important sources included wrong wearing position, angle dependence of response and fading.

Q2. How do you choose the calibration factor (e.g. the different application areas N1 to N4, according to DIN 6802-4? Who defines the calibration factor: the IMS or the customer?)

Two of the three IMSs reported using DIN 6802-4 [40] (currently undergoing revision), with one of these IMSs defining the calibration factor and the other making a recommendation which the undertaking either accepts or revises. The third IMS collaborates closely with the undertaking, making measurements of neutron spectra and arriving at suitable calibration factors.

Further likely causes of error are:

- magnitude of n-γ ratios (affecting determination of net neutron signal).
- effectiveness of dosemeter thermal neutron shielding, if used.

11 Conclusions and Recommendations

As in 2003 [18], it has been very instructive to examine the state of quality assurance in Europe. Although not all of the IMSs who were invited provided a response, the survey succeeded in covering a majority of the workers in Europe. The study can therefore be considered valid.

Amongst the notable findings were the following. These exclude points, already made in the text, that are dependent upon national or other requirements outside the control of the IMS.

The survey has demonstrated that the recommendations of the Commission in RP160 [7] are largely being followed. Because this is not always the case, however, recommendations are given below that reinforce and supplement those of RP160.

11.1 Quality Management

- A high proportion of IMSs report accreditation to or compliance with a formal management standard.
- A few IMSs are unsure of the distinction between quality management standards and type-test standards.
- There is wide acceptance of the importance of quality audits, although internal practices vary.

Recommendations

- *IMSs should adopt a quality management system (QMS) by following a formal standard (e.g. ISO 17025) and/or national requirements.*
- *IMSs should make sure they know the difference between type test standards (e.g. IEC 62387) and quality management standards.*
- *Quality system audits should be carried out at appropriate intervals. Note that intercomparisons are not "external audits".*

11.2 Dosimetric QA

- The importance of type testing and of traceability is widely recognised.
- In proficiency testing:
  - "international intercomparisons" are widely used, probably owing to the ready availability of EURADOS intercomparisons.
  - puzzlingly, the simple "dummy customer" method [29] is not widely used.

Recommendations

- *Traceability must be established (reference calibration)(RP160)[7], and should be checked at regular intervals, e.g two years.*
- *Proficiency Testing:*
  - *all IMSs should carry out some form of proficiency testing.*
  - *intercomparisons are recommended.*

- *dosemeters in intercomparisons should be processed in the same way as customer dosemeters, as far as the procedures allow.*
- *proficiency testing by "dummy subscription" is easy and all IMSs should do it.*

11.3 Uncertainties

- Almost all IMSs assess measurement uncertainty, but it is common to supply generic information, or information on request.
- Typical relative uncertainties, for whole-body photon/electron dosemeters with a coverage interval of k=1, lie in the range 0,11 to 0,15.

Recommendations

- *IMSs should assess the measurement uncertainties for all methods used.*
- *ALL sources of uncertainty should be considered (RP160 [7] includes examples)*
  - *radiation energy and angle of incidence (variation of dosemeter response) are often the most important factors.*
  - *precision and accuracy obtainable in the laboratory are not the same as those obtainable in normal use.*
  - *proficiency testing (e.g. intercomparisons) can provide useful method for checking the uncertainty assessment (measurement uncertainties should be consistent with the bounds established in the assessment, taking the scope of the proficiency testing into account).*
- *IMSs should make these assessments available to clients.*
  - *if not reported for each assessment, make them readily available.*

11.4 Practice

- The importance of eye lens dosimetry, of most importance in the medical sector, is expected to increase in the coming years, as the new EU Basic Safety Standard [16] is implemented.
- Some services measure eye lens dose in terms of $H_p(0.07)$ – this is only acceptable if there are no beta/ electron exposures.
- One third of IMSs do not record any value in the dose record when a dosemeter is lost or destroyed. This leads to incomplete dose records and the possibility of abuse.

Recommendations

- *IMSs that assess EYE LENS DOSE by means of $H_p(0.07)$ should not use this approach for electrons. $H_p(3)$ must be used in those cases.*
- *When a dosemeter is LOST or DESTROYED, some entry must be made in the worker's dose record – it should not be left blank.*
  - *Entry could be an estimated dose or a pro-rata notional dose.*
  - *May be responsibility of NDR.*

11.5 Causes of Error

- Causes of error remain largely as in 2003, with a few changes.
- Physical damage, and significant irradiation when not in use, are still amongst the most important causes of error.
- For the "traditional" methods of dosimetry (film and TLD), the chief causes of error remain similar to those in 2003.
- For newer methods used by small numbers of IMSs, the chief causes of error are being identified.

Recommendations

- *Common causes of error include wrong wearing position and irradiation when not worn. These can be addressed by IMSs by:*
  - *providing instructions and information aimed at individual wearers.*
  - *considering transit controls, packaging and delivery options to avoid transit doses including security x-rays.*

11.6 Summary

It is encouraging that the profile of QA is high amongst the responding IMSs, and that most are following good practice. The majority of services are accredited (around 70%) or declared themselves compliant to quality standards, mostly in accordance with EN/ISO/IEC 17025 [19] or with ISO 9001 [20]). Accreditation is increasing in importance for European IMS.

There is some evidence that harmonisation is still needed; some IMSs can learn lessons. More services need to pay attention to the topic of measurement uncertainty, for example, making a full analysis of all contributing factors, as recommended in RP160 [7]. Meanwhile, many services could improve their QA by means of a dummy customer subscription [29]. Internal audits, too, could be more widely used.

EURADOS is fully aware that harmonisation is a continuing goal for individual monitoring. Therefore EURADOS continues to support quality assurance in individual monitoring by disseminating its work through conferences, meetings and publications, by organising regular intercomparisons and by running training courses for middle managers and technical IMS staff.

Acknowledgements

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GLOSSARY

ADS	Approved Dosimetry Service
APD	Active (electronic) Personal Dosemeter
DIS	Direct Ion Storage
ESOREX	European Study of Occupational Radiation Exposure
EU-TRIMER	European Union – Technical Recommendations for Individual Monitoring of External Radiation. Project leading to report RP160, q.v. [7]
IAEA	International Atomic Energy Agency
IC	InterComparison (or, depending on context, Interventional Cardiology)
ID	Identifier
IEC	International Electro-technical Commission
IMS	Individual Monitoring Service
IR	Interventional Radiology
ISO	International Organisation for Standardisation
NDR	National Dose Register
NM	Nuclear Medicine
NORM	Naturally-Occurring Radioactive Materials
OSL	Optically-Stimulated Luminescence
QA	Quality Assurance
QC	Quality Control
RP160	See "EU-TRIMER" above [7]
RPE	Radiation Protection Expert
RPL	Radio-Photo Luminescence
TENORM	Technologically Enhanced NORM – naturally-occurring radioactive materials with concentrations/ activities that have been increased by human practices.
TLD	Thermoluminescence
WB	Whole Body
WG2	EURADOS Working Group 2

Annex – Excel Spreadsheet – The Questions

European Radiation Dosimetry Group EURADOS

EURADOS Working Group 2

Task 2 - Improving measurements, QA/QC, dose recording and reporting

SURVEY ON HARMONIZATION OF EXTERNAL RADIATION MONITORING 2012

Thank you for agreeing to take part in this survey, which will be used to promote harmonisation amongst dosimetry services in the European region.

The survey addresses many of the topics covered in RP160 (*), which can be found at:
http://ec.europa.eu/energy/nuclear/radiation_protection/doc/publication/160.pdf

PLEASE REFER TO THIS DOCUMENT WHEN COMPLETING THE QUESTIONNAIRE. In particular, you may need to consult the glossary on page 7.

The questionnaire is laid out as follows:

Section 1:	a confidential page of contact details (sheet "IMS").
Section 2:	six pages of questions about your practices for dosimetry and QA (sheets "General", "QA-Sys", "QA-Dos", "Practice", "Report1", "Report2"). Please complete all of them
Section 3:	detailed questions about sources of error. Please complete the "Errors-Common" page, AND any that refer to your specific dosemeter types. Please focus on those conditions that cause the most frequent, or the largest, errors. SEE NOTES ON THE "COMMON" PAGE.

The survey is intended to cover **individual monitoring only**. Please exclude data for dosemeters that are not used to measure individual worker doses.
Please provide the most recent data available

(*) *European Commission. Radiation Protection 160, Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation. European Commission, Luxembourg, 2009*

YOUR CONTACT DETAILS

CONFIDENTIALITY:
The information given in this section will not be used for evaluation and will be treated as CONFIDENTIAL.
EURADOS will only use these details to contact you, if we need to clarify anything.

Name of dosimetry service	
Acronym: (Abbreviation of your Service)	
Responsible person:	
Telephone number of responsible person:	
E-Mail of responsible person:	
Country:	
Date:	

GENERAL DETAILS about your IMS

Remember to exclude environmental and area monitoring dosemeters.

Box A: work sectors

Work Sector	Percentage of dosemeters issued
Veterinary	
Medicine	
Dentists	
Industry	
Nuclear industry	
Research	
Government/Armed forces	
TENORM	
Any others:	

Box B: categories

Number of workers monitored	
Number of workers in category A (if known)	

Box C: origin of data

Data in boxes A and B are

- ○ Estimated values
- ○ Exact values
- ○ Values based on the year

Box D: dosimeter types and change intervals

Please tell us how many dosemeters do you issue each year, and what percentage use "short" or "long" change intervals.

Type		Number of dosemeters issues by year	Change interval: Short (% 1 month or less)	Change interval: Long (% Greater than 1 month)
APD (only if used for official monitoring - number of readings)				
Whole body beta/gamma/x-ray	DIS			
	Film			
	OSL			
	RPL			
	TLD			
Whole body Neutron	Track Etch			
	Bubble			
Extremity (hands & feet) beta/gamma/x-ray	TLD			
Eye lens	TLD			
	Film			
	OSL			
	RPL			

Box E: lost and non-returned dosemeters

What proportion of dosemeters are not returned to you **within 6 months of the end of the wear period**?

- ○ Average about
- ○ I don't know

How much do you charge dosemeters for lost dosemeters?

We are asking about prices only to see the effect on the rate of loss

APD		€ each
DIS		€ each
Film		€ each
OSL		€ each
RPL		€ each
TLD		€ each
Track Etch		€ each
Bubble		€ each

QUALITY SYSTEM

Box F: What quality system do you use?

Multiple answers are possible

		Certified by third party
ISO 9000 series	☑ Compliant	☑ Certified
ISO 17025	☑ Compliant	☑ Certified
Other	☑ Compliant	☑ Certified

Internal procedure based on:

- ☑ RP 73 (EUR 14852)
- ☑ RP 160
- ☑ IAEA Safety Standard Series RS-G-1.3
- ☑ Other

Box G: What quality audits you undergo?

Multiple answers are possible

	Please give frequency of audits Interval	
External - formal quality standard e.g. ISO 17025		months
External - national arrangements (e.g. regulator)		months
Internal		months
Other		months

☑ None

Box H: Declaration of Compliance

Do you have to make an annual declaration of compliance? ☑

Who does this go to (e.g. regulator, certification body)?

Quality Assurance - Dosimetry

Box I: Type Testing

How have your dosemeters been type tested?

Multiple answers possible

- ☑ Not type tested
- ☑ IEC 61526 (APDs)
- ☑ IEC 62387-1 (Passive)
- ☑ ISO 1757 (Film)
- ☑ IEC 61066 (TLD)
- ☑ ISO 12794 (Extremity, Eye)
- ☑ Manufacturer has type tested
- ☑ National authority has type tested
- ☑ Other

What tests, if any, did you omit from the standards?

(Give most important exceptions)

What tests did you carry out, that were not in the standards?

(Give most important additions)

Box J: Traceability

What kind of laboratory do you use to ensure traceability to international/ national standards?

- ☑ Primary standard laboratory
- ☑ Secondary standard laboratory
- ☑ EA accredited calibration lab
- ☑ Other

How often do you check traceability to national / international standards?

- ◉ Every months
- ◉ Only when there is a change to the system
- ◉ We have no plan for this

Box K: Performance testing for approval

What kinds of performance testing, by external bodies, must you undergo in order to retain legal approval?

Please answer for your main system. Enter zero if not required.

	Interval	(Please state interval)
Announced - Blind test		months
Announced - "Part-blind" test, i.e. radiation quality known		months
"Surprise" - Blind test		months
None, but evidence of proficiency testing required		months

Box L: Proficiency testing

What additional proficiency testing do you carry out?

	Interval	(Please state interval)
Intercomparisons - international		months
Intercomparisons - national		months
Internal dummy customer subscription		months
Other		months

Dosimetry practice

Questions about non-standard situations

Box M: lead aprons

When a worker is using a lead apron, how do you assess effective dose?

- Not the responsibility of the IMS
- Single dosemeter under apron
- Single dosemeter over apron
- Double dosimetry (one over apron and one under)
- Other

If you use double dosimetry, please state what algorithm(s) you use. State a and b where the algorithm is:

$$E = a\,H_{under} + b\,H_{over}$$

	a	b
Algorithm without thyroid shield		
Algorithm with thyroid shield		

Other (specify):

Box N: Multiple dosimeters on same extremity

Do any of your clients wear more than one dosemeter on the same extremity (hand, foot etc.)?

- Maximum measured dose
- Mean measured dose
- Always the same location, e.g. finger

Box O: Eye Lens Dosimetry

How do you evaluate the dose to the lens of the eye?

- Whole body dosemeter worn on the trunk
- Whole body dosemeter worn on the collar
- Special dosemeter worn near eyes (e.g. forehead)
- Other
- Not evaluated

What dose quantity do you assess for the eye lens?

Photons Electrons

In what work categories do your clients monitor eye lens dose?

- General Industry
- Medical - IR/IC
- Medical - NM
- Government/armed
- Nuclear
- Veterinary
- Other

In which sectors do you expect this to increase if the eye lens dose limit is reduced to 20 mSv/y?

- General Industry
- Medical - IR/IC
- Medical - NM
- Government/armed
- Nuclear
- Veterinary
- Other

Box P: Parallel dosimetry

Parallel dosimetry means more than one IMS involved in monitoring at the same time. NOT lead aprons - see above. Example: contractors working on nuclear sites

Do you have situations in which workers wear dosemeters provided by two different IMSs at the same time?

- Whichever is the higher
- The one issued by the appointed IMS
- Decided by the RPE
- Decided by the national dose registry
- Other

Would guidance on parallel dosimetry be useful to you?

Box Q: Pregnant workers

How are doses to the fetus measured?

- Normal whole body dosemeter
- Additional dosemeter worn on abdomen

Is a conversion factor used?

Please give detail

Dose reporting - 1

Box R: Different IMSs

Summing doses from different IMSs, e.g. external + internal

Who sums the doses that come from different IMS?

- ◉ The IMS
- ◉ The RPE/Qualified Expert
- ◉ The national dose registry
- ◉ A separate record-keeping IMS
- ◉ This is not done
- ◉ Other

Box S: Multiple employments

Who sums the doses that come from different employments for the same worker?

Note - these could be measured by different IMSs

- ◉ The IMS
- ◉ The RPE/Qualified Expert
- ◉ The national dose registry
- ◉ A separate record-keeping IMS
- ◉ This is not done
- ◉ Other

Box T: Who receives the dose reports

To whom are the doses routinely reported?

Note: More than one response possible

- ☑ The employer/RPE
- ☑ The authorised medical doctor
- ☑ The national dose registry
- ☑ The authorities
- ☑ Other

Box U: What is routinely reported?

What is contained in the routine dose reports that you send?

Note: More than one response possible

- ☑ Dose for the monitoring period
- ☑ Cumulative dose for the year to date
- ☑ Cumulative five-year dose
- ☑ Components of dose (external/internal)
- ☑ Other
- ☑ Other

Box V: Missing doses

What is done when a dosemeter is lost or destroyed?

Specify primary option only

- ◉ Employer/RPE makes estimate
- ◉ IMS makes estimate
- ◉ IMS makes estimate and RPE authorises
- ◉ Pro-rata "notional" dose applied
- ◉ Pro-rata "notional" dose applied if no estimate received
- ◉ No value is assigned
- ◉ Other

Box W: Dose quantities

In which dose quantities do you report your dose values?

- ◉ Personal dose equivalent Hp(d) - mSv
- ◉ E, effective dose/ HT, equivalent dose - mSv
- ◉ Ka, air kerma - mGy
- ◉ Other

Box X: Assignment of Doses

How are workers identified for dose reporting and recording?

- ◉ National unique ID
- ◉ Unique ID issued by service
- ◉ Other

Dose reporting - 2

Box Y: Measurement Uncertainty

How have you assessed the measurement uncertainty of your system?

- ○ JCGM-100/ ISO GUM
- ○ EA-4/02
- ○ Internal procedure only
- ○ Manufacturer information
- ○ National authority type test
- ○ Other
- ○ We have not assessed it

How do you report measurement uncertainties to customers?

- ○ For each dose reported
- ○ Generic information leaflet
- ○ Only on request
- ○ Other
- ○ We do not report uncertainty

For your whole-body, gamma/x-ray dosimetry system, please state your overall standard uncertainty (k = 1). Include all sources of uncertainty (e.g. energy and angle response). Assume a 1-month issue period and a dose of 1 mSv.

Uncertainty:

k is the coverage factor, and k = 1 corresponds to "1 sigma"

Box Z: Natural Background

How do you deal with natural background?

Multiple answers possible

- ☑ Background not subtracted (passive dosemeters)
- ☑ APDs - background not subtracted but only accumulated for working hours
- ☑ Background/transit control dosemeters
- ☑ Batch controls, held at the service
- ☑ National average
- ☑ Regional or locality average
- ☑ Measured at customer site
- ☑ Other

Box AA: Threshold doses

For your whole-body photon dosemeter, what is the smallest positive dose ($H_p(10)$ or E) that you report?

mSv

What is this based on?

- ○ ICRP recording level
- ○ Detection limit of dosemeter (in laboratory)
- ○ Detection limit of dosemeter (in field conditions)
- ○ National requirement
- ○ Other

How are doses lower than this value treated in cumulative dose records?

- ○ Treated as zero
- ○ Other

Box AB: Reporting Method

Multiple answers possible

Which of these methods do you use for reporting dose to the customer?

- ☑ Printed report by mail or fax
- ☑ Electronic, file
- ☑ Electonic, online access
- ☑ Other

COMMON

BOX AC: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please answer these questions for your IMS.

Please choose the FIVE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 5.

In deciding what is "most important", take into account both the frequency and severity of the error. Use 1 for the most important source and 5 for the least.

		TOP 5 SOURCES
Irradiation	Significant irradiation when not being worn	
	Malicious exposure	
Contamination	Contamination - radioactive	
	Contamination - detergent (machine washing)	
	Contamination - sterilising agents	
	Contamination - other chemical	
Damage	Physical damage during use	
	Physical damage after receipt at IMS	
	Loss of dosemeter identification (barcode obliterated etc.)	
	Loss of wearer identification (loss of link to dosemeter)	
Wrong use of dosemeter	Wrong wearing position	
	Wrong position in holder	
	Incorrect storage/shipping	
Miscellaneous	Inappropriate dose calculation algorithm	
	Loss of data during processing or recording	
Other:		
Other:		
Comments:		

APDs

BOX AD: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Pulsed fields	
Electromagnetic interference	
Climate effects (temperature, humidity)	
No power (battery fault)	
Electronics fault	
Other:	
Other:	
Other:	

DIS

BOX AE: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Dose range/linearity	
Electromagnetic interference	
Climate effects (temperature, humidity)	
Dosemeter fault	
Reader or system fault	
Other:	
Other:	
Other:	

Film (Photographic)

BOX AF: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Film opened (light exposure) during use	
Climate effects (temperature, humidity)	
Light exposure during processing	
Unstable developing/fixing conditions	
Increased batch inhomogeneity	
Incorrect energy correction/ Incorrect mean energy determination	
Holder\ filter integrity	
Unstable densitometer	
Human factor in optical density measurement	
Incorrect correction of fogging	
Other:	

OSL

OSL = Optically stimulated luminescence - all materials excluding phosphor glass - see RPL

BOX AG: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Light exposure of the sensitive element	
Increased batch inhomogeneity	
Failure of illumination system	
Failure of read system	
Faulty filter pack/ holder	
Other:	
Other:	

RPL (GLASS)

BOX AH: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Unstable pre-heat treatment	
Unstable pre-irradiation annealing procedure	
Pre-dose incorrectly taken into account in the dose calculation	
Unstable reading conditions (laser unstability)	
Increased batch inhomogeneity	
Other:	
Other:	

TLD

BOX AI: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity of the error.
Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Error in the heating system	
Error in PM-Tube system (high voltage …)	
Unstable (changing) individual detector correction factor	
Increased batch inhomogeneity (if individual detector correction is not used)	
Unstable (changing) individual detector intrinsic background signal	
Irregular glow curve (e.g. spurious peaks)	
Chemical contamination of detector (dirt …)	
Incomplete read out	
Unstable Pre/post annealing procedure	
Other:	

TRACK ETCH

BOX AJ: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity of the error.

Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Unstable etching conditions	
Increased batch inhomogeneity	
Increased / variable intrinsic backgrounds	
Intrinsic background varies across sheet	
Human factor (if manual read out)	
Quality of material	
Other:	

BUBBLE DOSEMETERS

BOX AK: SOURCES OF ERRORS OR INCREASED UNCERTAINTY

Please choose the THREE most important sources of error or increased uncertainty in your system, and rank them by entering a number from 1 to 3.

In deciding what is "most important", take into account both the frequency and severity

Use 1 for the most important source and 3 for the least.

	TOP 3 SOURCES
Environmental conditions (temperature/ humidity etc)	
Dose range limitiations	
Reading problems (assessing bubble count)	
Incompressible bubbles	
Shock/ vibration/ microphony	
Variable dosemeter sensitivity	
Other:	