HERCA

HEADS OF THE EUROPEAN RADIOLOGICAL PROTECTION COMPETENT AUTHORITIES

HERCA Network on Occupational Dose Collection, Registration and Reporting

Report on the outcome of the questionnaire: Occupational exposure and dose registration

April 2024

Approved by the Board on the 23rd of May 2024

Index

Summary

This document describes the outcome of the survey that was carried out in 2021 by the HERCA Network on occupational dose collection registration and reporting. The objective of the survey was to collect information on the challenges and open-ends with regards to occupational exposure and dose registration.

The survey consisted of 12 topics related to occupational exposure and dose registration. Each of the topics contains a series of questions to identify current practices on individual monitoring of exposed workers and arrangements on establishing and maintaining the national dose register by HERCA members. In addition, questions were asked about recent changes in national regulation, challenges and open-ends and ideas for future topics to be worked on by the HERCA network. A total of 24 questionnaires were received from the HERCA members, indicating substantial interest in the field of occupational exposure. The suggestions for future work reveal that guidance on scientific and regulatory aspects of occupational dose monitoring and collection are welcomed. In addition, there is a strong interest among the HERCA members to share aggregated dose.

Regarding the national dose register many HERCA members are presently working on the modernisation of their register such as digitisation and automation of the dose collection, as well as improving the completeness of the dose records. It is also concluded that there exists considerable variation in the collection of dose information particularly for exposures such as radon and eye lens.

Considering the extensive list of suggestions for future work items it is concluded by the network that future work should focus on issues directly related to improve the operation of the national dose register. Furthermore, the network should collect and interpret aggregated data on occupational dose exposure to facilitate the needs in other HERCA Working Groups. For this reason, the ODCRR network suggests that its future work should focus on the following topics:

- Use the network as a platform allowing people in charge of the national dose register in their countries to exchange on good practices, encountered difficulties, and experiences learned in the context of the operation of the NDR’s. The network could focus on present practice in radon dose collection, deal with the exchange of data between countries for the follow-up of cross-border outside workers and digitization, IT security, digital dosimetry and data protection.
- From this exchange the HERCA network could obtain overviews and identify best practise in the field of dose collection, recording and reporting.
- As part of this exchange aggregated dose information will be collected which will facilitate the activities in other HERCA WG’s. For the collection of the aggregated data the European platform for Occupational Radiation Exposure (ESOREX) platform would be the preferred platform.

1 Introduction

European Directive 2013/59/Euratom sets the basic framework for national legislation on occupational and public radiation protection in all member states. That means that the member states have to implement the directive into national legislation. However, the implementation of the framework is left to the individual countries, which may lead to a different way of dealing with details in different national legislations. In addition, transnational issues might not be sufficiently regulated and solved by this procedure of national transpositions. This also applies, among other things, to the national regulations on occupational radiation protection and monitoring and all related regulatory aspects. The specific guidelines for radiation passbooks, for outside workers as well as radon or eye lens monitoring are such examples which may be regulated differently in different countries.

In order to obtain a comprehensive picture at the international level and furthermore to collect information on the challenges and open issues related to occupational radiation protection and monitoring, a survey was prepared by the HERCA Network on Occupational Dose Collection, Registration and Reporting (ODCRR) to be submitted to all HERCA member organisations. This action was mandated in October 2019 by the HERCA Board outcome H24-7[1].

The survey consists of 12 sections related to occupational exposure and dose registration. Each of the sections contained a series of questions to identify current practices on individual monitoring of exposed workers and arrangements on establishing and maintaining the national dose register in HERCA members. In addition, questions were asked about recent changes in national regulation, challenges and open-ends and ideas for future topics to be worked on by the HERCA network.

After the first draft of the questionnaire was submitted to the HERCA Board for approval in December 2020, it was finally approved in February 2021. Subsequently, the questionnaire was sent to the HERCA National Contact Points by the HERCA Technical Secretariat in March 2021. The target audience for the survey should be the regulatory and competent authorities with expertise in occupational exposure and dose registration in each country. The HERCA contact points were asked to provide a maximum of one feedback for their country. This probably posed challenges for some participants in so far as in some countries different organisations might be responsible for different types of information. To cover the overall status of a country, bringing all types of information together is crucial.

By June 2021 a total of 24 questionnaires had been received from the member states. Since then, the information provided in the questionnaires has been processed and evaluated. A full summary of the results of the assessment is included in this document. The document starts with an overview of the main findings of the survey. After that, the document follows the same structure as the questionnaire and provides a thematic summary for each section of the questionnaire. The first two sections of the questionnaire "1. National Competent Authorities" and "2. National Legal Framework" are not included in the analyses for the time being, as they mainly provide general information about the respondent and its organisation.

[1] Outcome H24 - 7 | HERCA network ODCRR: The Board supports the network ODCRR initiatives to perform a survey among HERCA members on the experiences and challenges with regards to Assessment of Occupational Exposure and National Dose Registries and asking for opinion on the proposal to refresh this initiative within HERCA members as base for further work.

2 Setup of the questionnaire

2.1 Background

In order to define the future work planning and target areas for the ODCRR network, the proposal to perform a survey among HERCA members was presented in October 2019 to the meeting of the board of HERCA which approved this initiative. The objective of the survey was to collect information on the challenges and open-ends with regards to occupational exposure and dose registration.

2.2 Methodology

A draft of the questionnaire was prepared by the HERCA ODCRR Network in 2020, and was submitted to the Board of HERCA for approval via a silent procedure. The final version of the questionnaire was approved with minor comments & suggestions in February 2021 and was submitted to the HERCA national contact points in March 2021. The deadline for response from the HERCA members was May 2021. The survey consists of 12 following sections related to occupational exposure and dose registration:

- National competent authorities
- National legislative framework
- National dose register
- National report
- Radiation passbook
- Recognised dosimetry services
- External exposure - whole body dosimetry
- Extremities/skin dosimetry Topic 1.
- Eye lens dosimetry
- Aircrew exposure
- Internal exposure (not including radon)
- Radon

Each of the sections contains a series of questions to identify current practices on individual monitoring of exposed workers and arrangements on establishing and maintaining the national dose register in HERCA members. From section 4 onwards (national report) the relevant sections are completed with questions to establish: recent changes in national regulation, challenges and open-ends, and any interest as a future topic for the network.

3 Outcome of the questionnaire

3.1 General outcome

A total of 24 countries from the 32 countries participating in HERCA have responded to the questionnaire. The respondents were generally providing very supportive and constructive ideas to the ODCCR's initiative. There is a strong interest for sharing aggregated dose information under the umbrella of HERCA. Further to this, many of the technical topics received high scores, with *national dose register*, *eye lens* and *radon*, receiving a score above 4 (range 1-5). The best score by a small margin was radon with an average of 4.5. Figure 1 gives an overview on the interest for future work on each of the technical topics. In addition, many suggestions, ideas and challenges have been raised by the responders to motivate their individual scores, which are presented in the topical sections below.

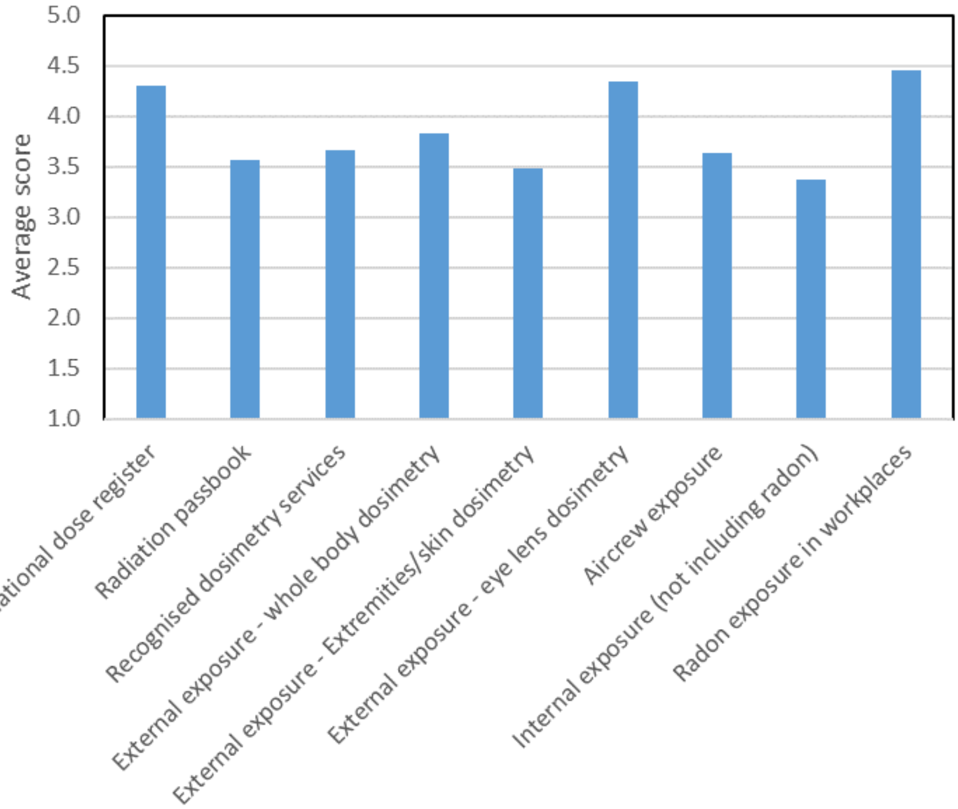

Figure 1 Scores (range 1 to 5) for the technical topics to be considered as a future work item for the HERCA network[2]

An informative visualisation of the questionnaire responses is the two-word clouds presented in Figure 15 and Figure 16. The first figure refers to the recurring question on *challenges* and the second refers to the *recommendations*. The word count is based on the response from all respondents in all aforementioned topics. The words dose, worker, dosimeters, eye dosimetry, services and radon dominate amongst the challenges reported by the respondents. The dominant words found in the recommendations are: dose, EU, HERCA, discuss, monitor, exchange, practice, eye and radon.

[2] The scores are obtained from the following question in the survey - *Would you recommend (name of the topic) to be considered as a future topic for the HERCA network? 1(no) 5 (yes)*

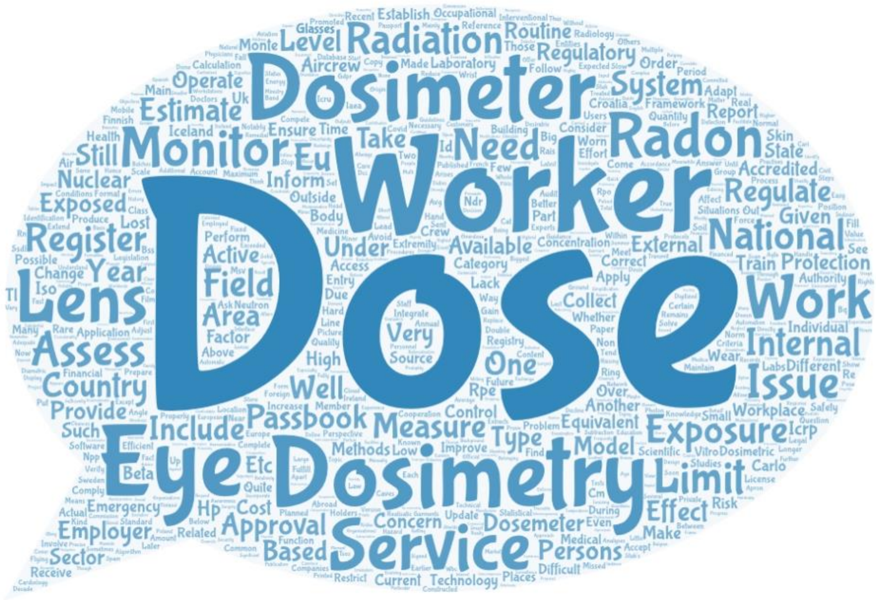

Figure 2 Word cloud for challenges.

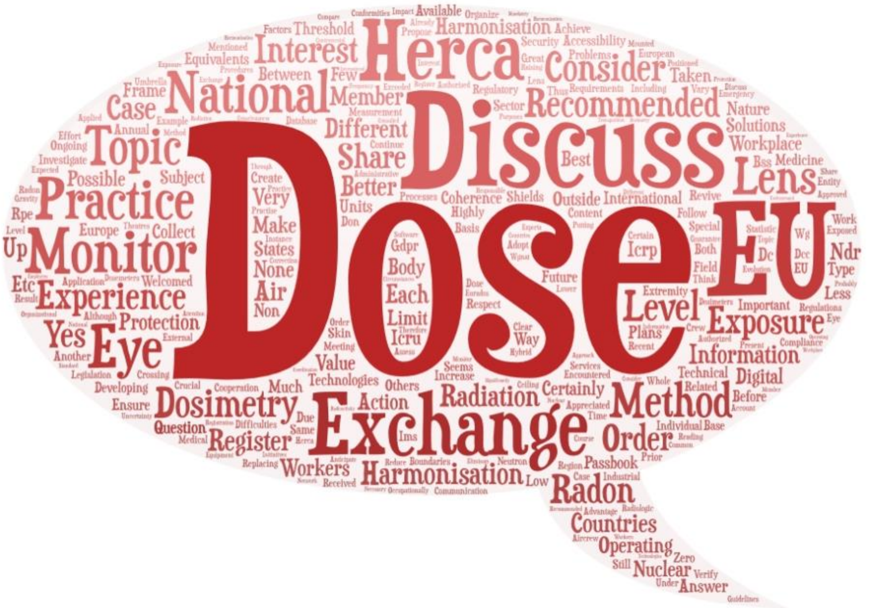

Figure 3 Word cloud for recommendations.

3.2 Outcome per topic

A summary on the outcomes of the questionnaire for each of the topics is presented in this section of the report. Special attention is given to the main findings and the individual challenges reported by the responses.

3.2.1 National dose register

Approximately 50% of the countries responded that regulations regarding the national dose register have changed due to the recent implementation of the EU-BSS. Adaptation of the regulatory framework to comply with EU-BSS requirements involved multiple changes. In general terms these changes were related to the content of the register such as, separate recording of the doses received in accidental, emergency situations or under special authorization. Other changes included the specific responsibilities of those involved in transferring the dose records to the dose register, the description of the modalities of these transfers, access to the dose register by the workers. Furthermore, there were changes regarding the role of the competent authorities, the employers, the occupational physician, and new regulation for personal data.

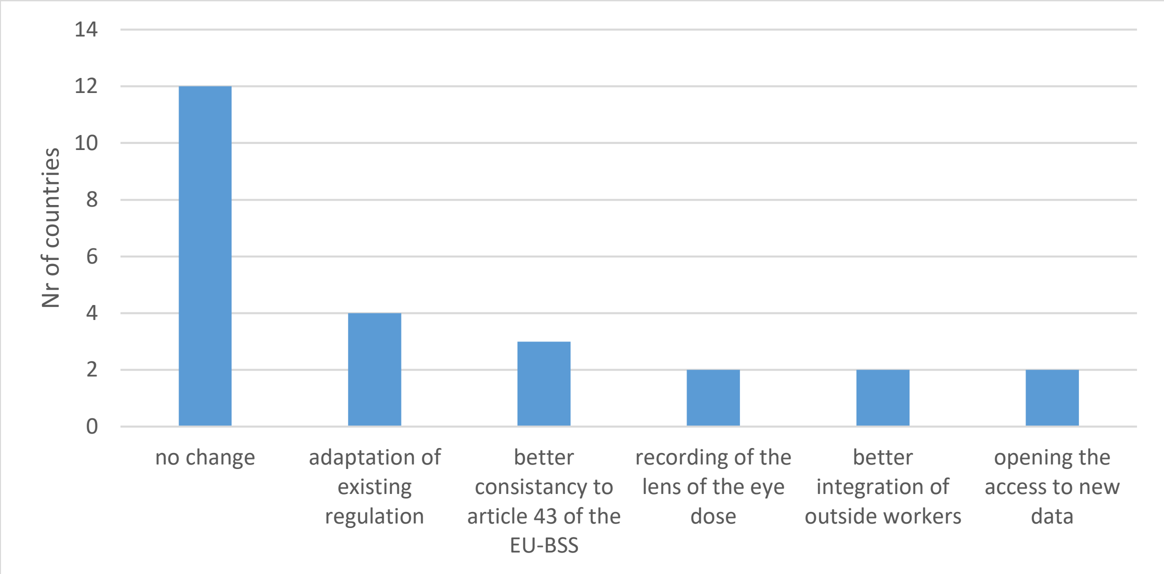

Figure 4 The change in regulations regarding the NDR Q. 2.1 (24 countries).

Following challenges regarding operation of the national dose register were expressed. Where appropriate the number of countries is included:

- to modernize an existing system - generally speaking and more precisely regarding digitization, IT security and data protection, rationalization, costs reduction, … [3 countries];
- to automatize the collection of particular data (internal dose, neutron exposure, corrected doses by RPE after application of correction factor for extremity dose for instance, …) [2 countries];
- to include workers that are not yet in the register (aircrew doses, exposure to other natural radiation sources, outside workers or “mobile” workers, workers of undertakings…) [3 countries];
- to deal with the fact that category B workers could not be included in the register;
- to increase to quality of data (especially missing data on occupational group and activity of worker) and improving the possibilities of statistical outputs [3 countries];
- to open or optimize the access to data for different actors (RPE/RPO, occupational medical doctors, workers…) [3 countries];
- to deal with the need of international cooperation/data exchanges between NRDs;
- financial impact from decline in radiological workers: compliance with GDPR.

Seven countries agree with or highly recommend to consider the national dose register as a topic for the HERCA ODCRR, with the aim to exchange good practices, encountered difficulties, and share experiences for a better harmonization; deal with the exchange of data between countries and exchange regarding digitization, IT security, digital dosimetry and data protection.

3.2.2 National report

Twenty-four countries responded to the questionnaire, among them 17 countries write a national report, which is mostly an annual report. Only one country writes a report once every five years.

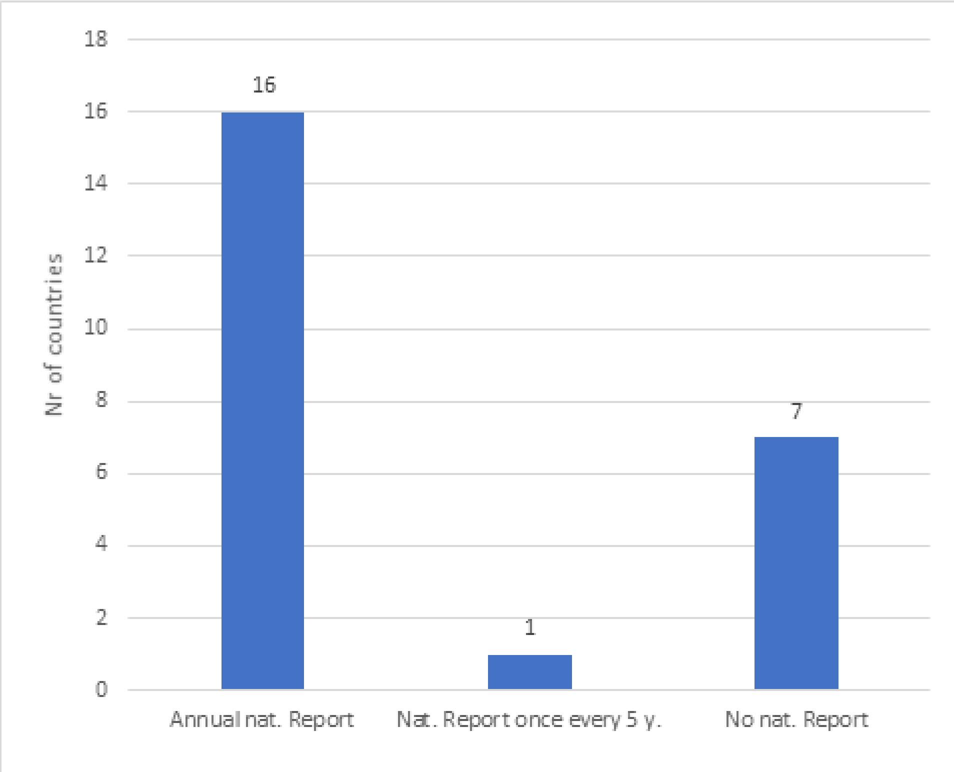

Figure 5 The frequency of annual report Q. 4.1 (24 countries).

Among the countries that responded only five of them make the national report available in English and eight other countries will consider a translation.

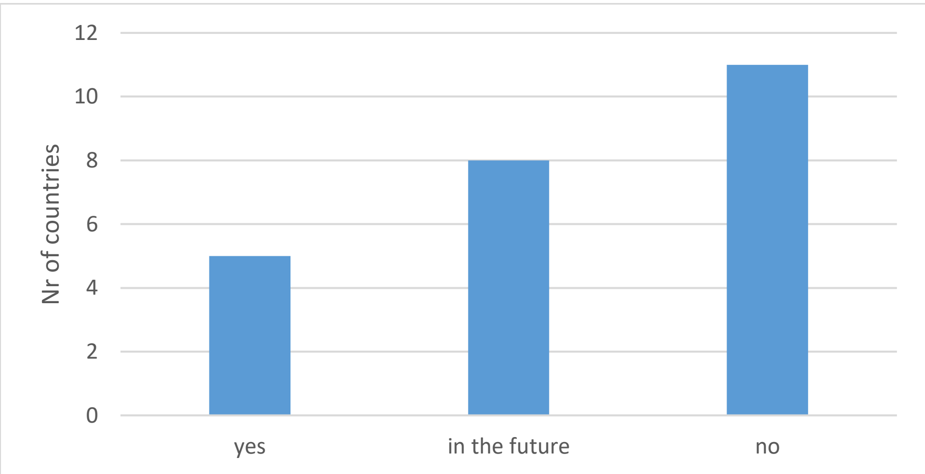

Figure 6 Translation in English of the annual report, Q. 4.2 and 4.3 (24 countries).

3.2.3 Radiation passbook

HERCA questionnaire was answered by 24 countries. From these, 21 countries use the Radiation Passbook and 1 country is in the process of preparing it. 2 countries do not use Radiation Passbook. For 9 countries data for the number of companies that employ outside workers and the number of outside workers is not available. For the rest (15) countries the number of companies ranges from 2 to 2700 and the number of outside workers from 47 to 50.942. For the majority of the countries (62.5%) the Radiation passbook is in hard copy form and a 29.2% is electronic (including printable pdf). The 8.3 % do not use passbook at all (Figure 7).

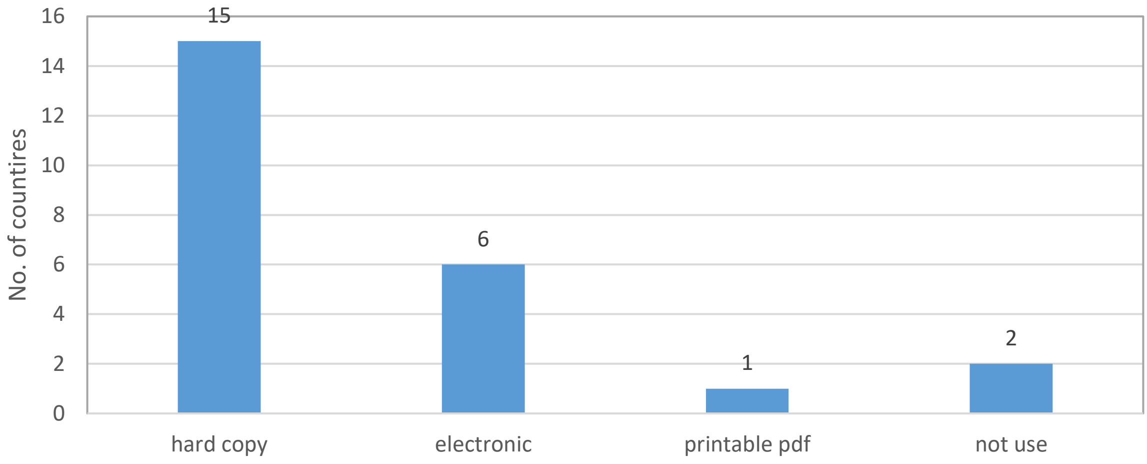

Figure 7 The types of radiation passbook Q. 5.4 (24 countries).

In half of the countries, outside workers use in parallel passive and active dosemeter, 12% of countries use passive dosemeter, while 30% of the countries use combinations of the two types of dosemeters depending on the work category, the type of radiation and the classification of workers to A or B category (Figure 8).

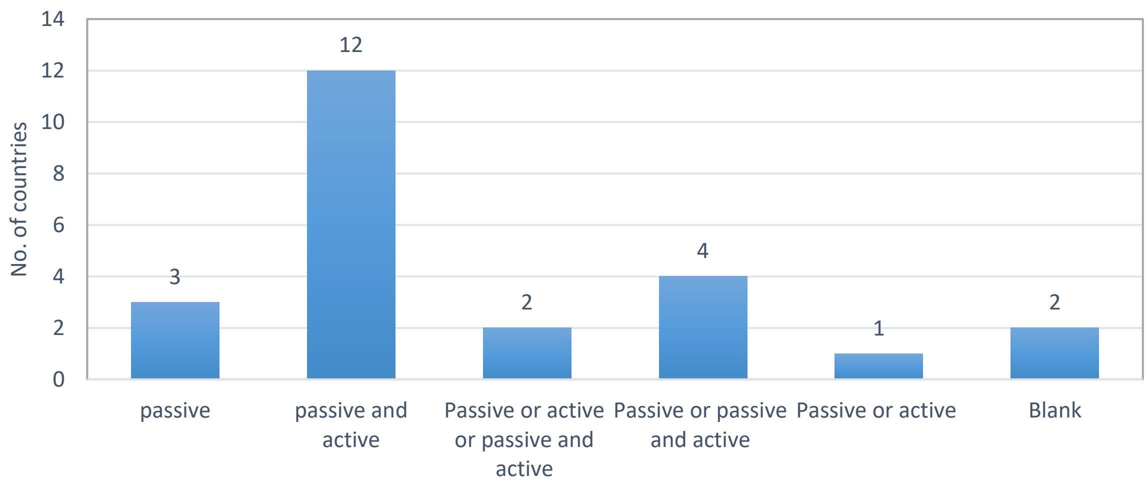

Figure 8 The type of dosimeters used by outside workers, Q. 5.5. (24 countries).

A total of 18 countries answered that they ensure the follow up of outside workers who move from their home country to other countries using Radiation Passbook. From these countries, 1 country answered that the employer is obliged to report the dose from the other country to the national dose register (dose from other country is recorded manually into the national dose register) and 1 country requests an individual certificate (hard copy). 6 countries did not answer.

Regarding the radiation passbook and the new EU-BSS, 10 countries answered positive that have changes in regulations in order to implement the directive. Following challenges related to the radiation passbook were expressed by the individual respondents.

- 50% of the comments refer to the necessity for an electronic radiation passbook using cloud technology, mobile applications, etc.
- There are different views about workers of category B. Some countries recommend for them not to receive the passbook while others suggest that this issue has to be discussed.
- Dose handling for outside workers who work in multinational companies (cross border workers)
- Information and promotion to stakeholders, relevant to the benefits from the use of radiation passbook.
- A common electronic radiation passbook all over Europe is recommended by some of the respondents.
- Some respondents suggest that the radiation passbook could be a part of the national dose registry

Regarding the discussion of radiation passbook in next HERCA topics, opinions appear neutral to quite positive with score 3.57 out of 5.

3.2.4 Recognised dosimetry services

From the 24 countries 16 countries declared no change in regulations regarding dosimetry services due to the recent implementation of the EU-BSS. Among the 7 countries who reported some changes, 3 of them now require an ISO 17025 accreditation for approval of the dosimetry services. Two countries have planned an update for approval in 2022, which will consider the recommendations of the RP160[3]. Other changes that were reported by the responders are: accreditation of $H_p(10)$ and $H_p(0.07)$ measurements, the duration of the dosimetry services approval (perpetual instead of 5 years), the data format regarding the recorded doses, the implementation of a unique identification number, and the applicable dose limits.

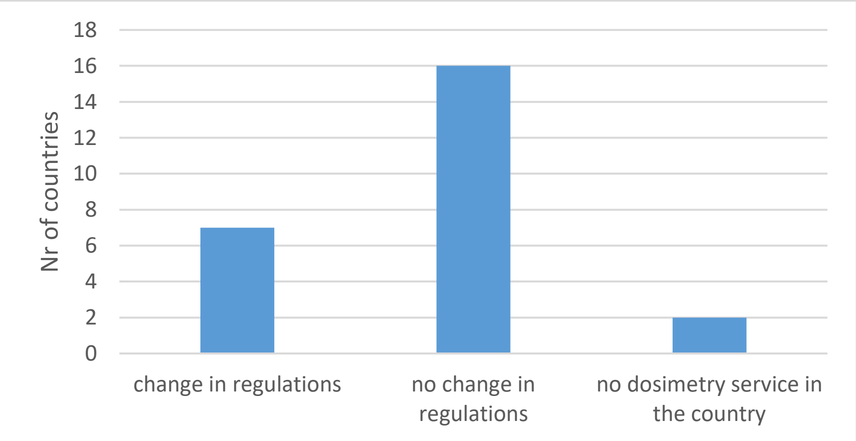

Figure 9 Change of regulations regarding the dosimetry services, Q. 6.3. (23 countries).

[3] Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation, Radiation Protection Series No 160, EC, 2009.

Following challenges regarding the dosimetry services have been expressed. Where appropriate the number of countries is included:

- maintain a sustainable business activity (financial difficulties, competition with big private enterprise entering the market, viability of dosimetry service if only category A workers are monitoring, ensuring an adequate infrastructure of dosimetry services) [4 countries];
- accreditation of all process / evaluation and approval of models used by dosimetry services to assess the doses, especially in extremity or eye lens equivalent dose evaluation [3 countries];
- background subtraction;
- sources of uncertainty (energy and angle);
- replacement with new technology: obsolescent technology to abandon or emergent technology to adopt (active dosimeters, “smart like” technologies) [2 countries];
- intercomparison tests;
- dosimetry in case of nuclear emergency.

Only 4 countries out of 24 consider the dosimetry services as a future topic for the HERCA network. Suggested work items include, harmonization of the requirements on approval, exchange of information, namely on new technologies or methods, and good practice regarding administrative and organizational aspects. One country stated that even if useful, this topic seems less crucial than other topics. One country did not see this topic as interesting. The 18 other countries did not answer this question.

3.2.5 External exposure - whole body dosimetry

Regarding whole body dosimetry for external exposure, the numbers of workers who are routinely monitored range from 400 persons to almost 400,000 persons per country. These numbers are certainly dependent on the size of the country and the question which category of workers are included in routine monitoring.

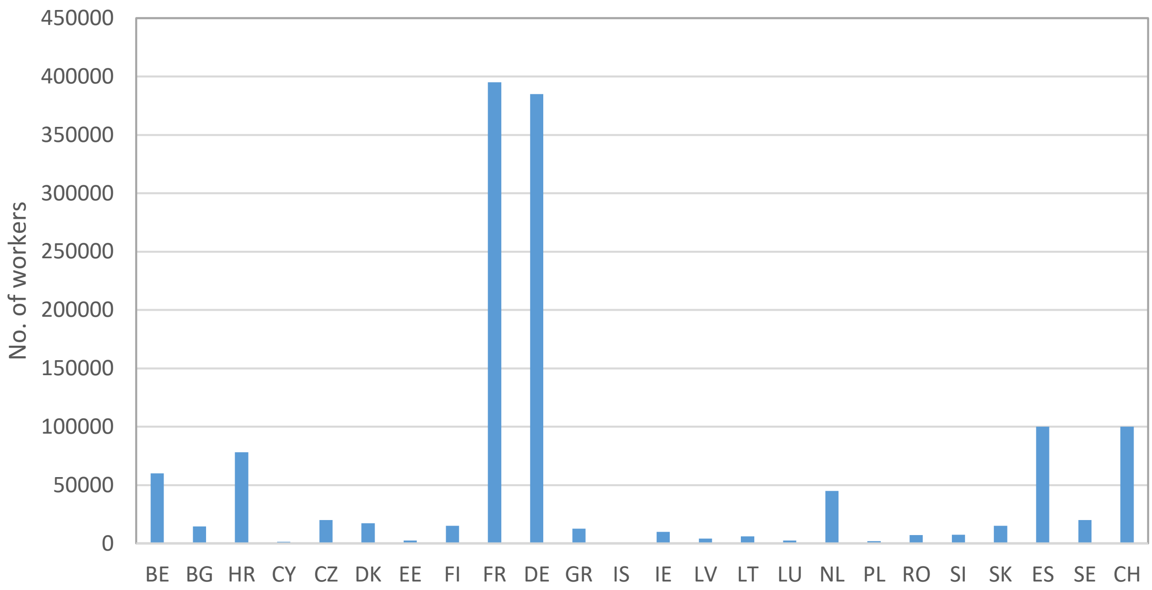

Figure 10 The number of workers routinely monitored by whole body dosimetry per year.

Besides category A workers, who are monitored in all 24 countries, category B workers are additionally routinely monitored in 17 countries. In 11 out of 24 countries the general monitoring period is 1 month. In 4 countries the monitoring period ranges from 2 up to 4 months. In 8 cases the period depends on the category of workers, 1 month for category A and 3 months for category B.
In most cases (17 out of 24 countries) there is no legal framework that recommends background correction. However, in some countries out of these, background correction is performed anyway due to technical guidelines. The other 7 countries do perform background correction on a legal basis.
With respect to the challenges in the field of external exposure, changes in operational quantities by ICRP or in protection quantities by ICRP are seen as a practical problem, since the measurement or calculation of doses might be difficult with existing dosimeters or existing dosimetry know-how. To solve this, investments in new dosimeters and education have to be performed which seem to be challenging. In addition to that, practical questions regarding the use of protection garments, the use of two dosimeters, position of dosimeters (e.g., under or above apron), the correct use of algorithms, which are all items that define the correct estimation of the effective dose are seen to be important and a harmonisation between countries should be performed. Other challenges, which have been mentioned by the different countries, are related to the new technological developments, as for example real-time monitoring based on Monte Carlo simulations, hybrid dosimeters or in general new types of personal dosimeters. These developments are emerging quite quickly, and the regulatory framework may have to be adapted to take this technical evolution into account. Some other concerns were about the acceptance of new regulations or new dose limits in practice, that some regulations are simply misunderstood or sometimes improperly implemented, e.g., inadequate use of dosimeters etc.

In detail, following challenges regarding whole body dosimetry have been expressed:

Technological developments

- In the years to come, technological developments are to be expected regarding to dosimetry monitoring, such as real-time dose monitoring based on Monte-Carlo simulations for certain workstations with greater risks. Ultimately, the regulatory framework may have to be adapted to take this technical evolution into account.
- Development of new types of personal dosimeters, modelling of expected personal doses in model situations (Monte Carlo calculation).
- hybrid dosemeters
- If ICRU changes the operational quantitates.
- For the individual monitoring services that use dosemeters that are no-longer produced the replacement with new technologies and proper trainings.
- Approval of electronic dosimeters for routine monitoring, NORM dosimetry

Scientific and regulatory developments

- From the scientific perspective, I believe that changes in operational dose quantities, proposed by the ICRP, would pose a problem in the future if existing dosimeters would not be able to measure the new quantities properly. Another issue is effective dose assessment in case of double dosimetry and equivalent dose to hands assessment with new quantities, since current algorithms might not be appropriate. This would also require related changes in dose limits and additional education of exposed workers to understand and accept how this change might affect them. The issue is how to correlate the current and the future individual doses in the national dose registry. The framework for education in dosimetry in our country is not established, the professionals are relying on available education in other Member states which is often not available in English or not available due to financial constraints. The Covid-19 pandemic makes difficult to attend practical trainings and this would probably extend to whole 2021. The expansion of development of electronic dosimeters would require change in legislation to allow use of such dosimeters in normal working conditions with restrictions considering their limitations for use in pulsed radiation fields.

Implementation and interpretation of regulations

- In the medical and veterinary field there is a tendency to change class A work to class B work or to use a group dosimeter. Therefore, the complete picture of the radiation exposure in all fields may be lost.
- e.g., inform/train emergency workers to gain acceptance of new regulations/system of dose reference levels, because EURATOM regulations/national regulations are sometimes misunderstood by emergency workers – emergency workers have concerns that reference levels might be too high, but also to restrictive (i.e., to low) to perform their duties
- Harmonization in cases where radiation protection garments are used and hence double dosimetry is (or is not) required. Position of dosimeters, algorithm to be used, in which cases to wear one/two dosimeters etc
- Neglect on behalf of the workers or their employers. Sometimes improper care and/or usage of dosimeters lead to data errors.
- Double dosimetry – when dosemeter under apron underestimates the operational quantity $H_p(10)$ but it is complicated for exposed worker to use 2 dosemeter (one under apron and the other above).

- The scientific methods and procedures for external exposure are well established and implemented in Spain. In contrast, from the regulatory perspective, the adequate use of the dosimeters by the users in the medical sector has always been an issue. It is also quite complex to guarantee the representativeness of the doses received on the National Dose Register, compared to the doses effectively received by the workers: monitoring should involve more than just the actual measurement. It should include interpretation, assessment, investigation and reporting. All those processes are quite difficult to regulate and to control.
- Monitoring radiation doses in our country for rare practises, i.e., neutrons and internal exposure

Infrastructure/capacity

- Availability of service since all 5 Approved Dosimetry services are outside the EU.
- There is too small number of organizational entities which are conducting monitoring of dose equivalents concerning external exposures of workers.

3.2.6 Extremities/skin dosimetry

The HERCA questionnaire was answered by 24 countries. Out of these, extremity doses were measured and recorded in 22 countries. They were under development in 1 country, and they were not measured and recorded in 1 country. Depending on the country, 15 to 28.000 workers were monitored for extremity doses per year (Figure 11).

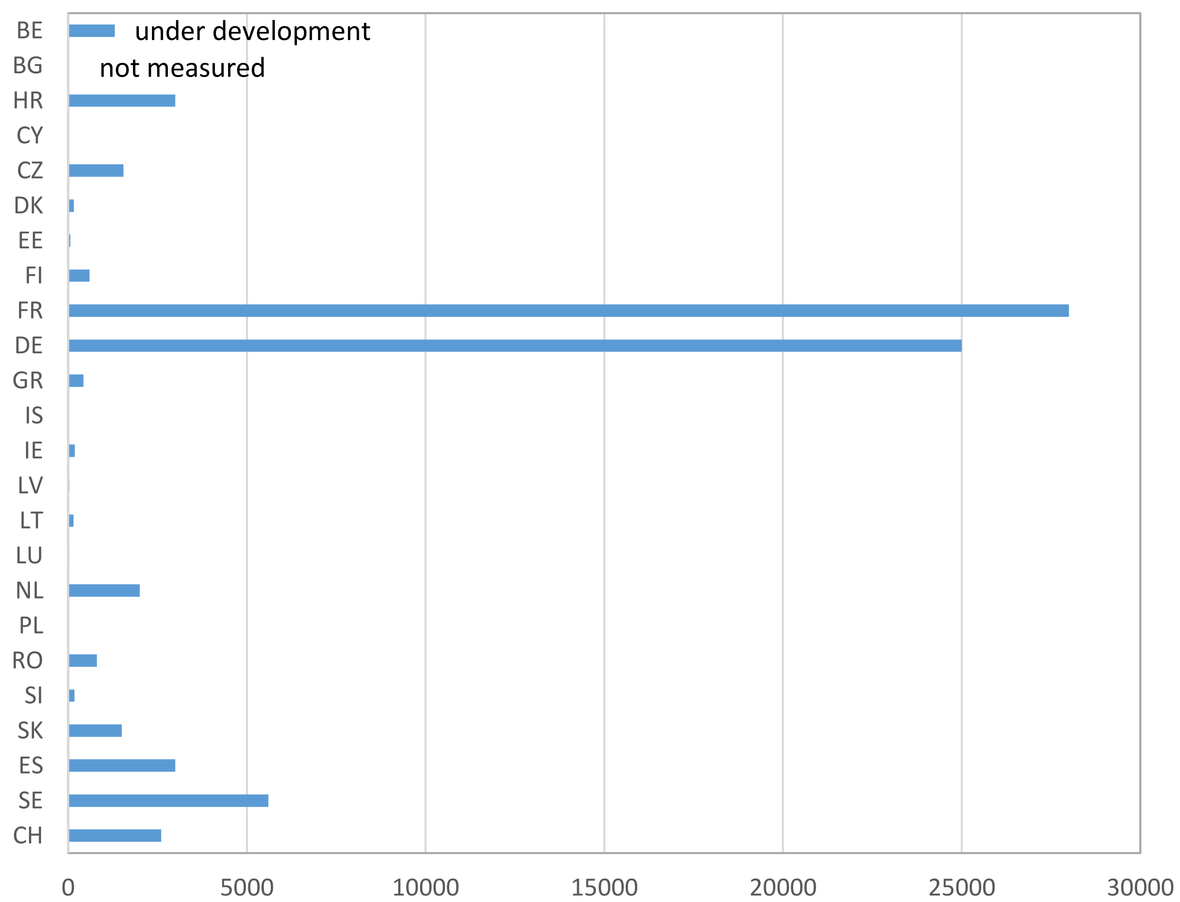

Figure 11 The number of monitored workers for extremity doses.

The operational dose quantity used for monitoring the extremities was $H_p(0.07)$ in 21 countries and both $H_p(0.07)$ and $H_p(10)$ were used in 1 country.
The extremities were monitored with both finger and wrist dosimeter in 13 countries and with finger dosimeter in 8 countries. Workers used one extremity dosimeter in 11 countries, one or two extremity dosimeters in 6 countries and two extremity dosimeters in 2 countries.
Position of the dosimeter in nuclear medicine, research, and education was under the glove in 18 countries and both under and over the glove in 1 country. The gloves were not used in 1 country. The position of the dosimeter in interventional medicine was under the glove in 16 countries. The gloves were not used in 1 country.

If extremity doses were not measured, correction factors were applied for estimation in 3 countries, and they were not applied in 15 countries. None of the countries provided a quantity used for correlation. In 1 country a correction factor of 5 must be applied for manipulations with open sources. Alternatively, an individual factor can be determined. In another country, if the dosimeter is not worn at the most exposed location, a correction factor taking into account the distance between the dosimeter and the most exposed part of the skin is determined and used to estimate the dose. In 1 country correction factors are applied when the dosimeter is worn on arm for glove-box work in nuclear activities.

In case of a contamination, workers skin exposure was calculated more specifically in 11 countries and not calculated more specifically in 9 countries. Calculations were under development in 2 countries. In case of contamination, the number of workers whose skin exposure was calculated was available in 7 countries. The skin exposure was calculated for only very few workers; 0 - 10 workers per year. Skin exposure calculations were done manually in 8 countries, both manually and using a program in 2 countries and using a program in 2 countries. When a program was used, it was either Varskin or MicroShield.

Regulations regarding extremities/skin exposure have not changed due to the recent implementation of the EU-BSS in 20 countries. Regulation have changed in 3 countries. In 1 country, dose limits concerning external exposure - extremities/skin dosimetry were lowered. In another country, the biggest change is the requirement that the undertaking must seek some advice from the RPE regarding the type of dosimeter and the wearing position appropriate for worker/workplace. In a third country the EU BSS was implemented with the terms and conditions for performing individual dosimetric control of persons working with sources of ionizing radiation.

Following challenges regarding extremities and skin dosimetry were expressed:

Dose assessment for extremities

- Realistic estimation of extremity dose (highest dose usually at fingertips).
- Algorithms for the assessment of the maximum dose in any 1 cm^2 area.
- The need to apply correction factors to take into account the use of protective garments as well as the difference between the maximum dose area and the location of the dosemeter.

Dose assessment for skin exposure

- The estimation of the skin exposure in case of contamination would require precise input data, which is practically impossible to get. The RPEs would require additional training in that field.
- There is too small number of organizational entities which are considering monitoring of dose equivalents for skin concerning external exposures of workers.
- To develop guidance for operators how to better monitor skin doses and what to do in case of overdoses.

General

- A problem is to stimulate and convince medical doctors in interventional radiology and interventional cardiology to use ring or wrist dosimeters. Maybe the effort should be put to find more comfortable ring holders.
- Complying with the requirements of ISO 15382 will require adaptation efforts in the field.

Technological development

- The biggest challenge would be for dosimetry laboratories to provide measurements of beta radiation since their ring/wrist dosimeters have only one detector calibrated for $H_p(0.07)$ photon measurements.
- Development of new types of personal dosimeters, modelling of expected personal doses in model situations (Monte Carlo calculation).
- Availability of electronic dosemeters for extremities.

3.2.7 Eye lens dosimetry

The eye lens doses were measured and recorded in 15 countries. They were under development in 5 countries, and were not measured and recorded in 5 countries. Depending on the country, eye lens doses were monitored from 0 to 92 000 workers per year (Figure 12). These 92 000 eye lens doses were monitored via whole body dosimeter, only a few via eye lens dosimeter.

Workers use one eye lens dosimeter in 13 countries and 1 or 2 eye lens dosimeters in 1 country. The position of the dosimeter varied considerably between the countries as listed in Table 1. The eye dosimeter was used over the protective glasses in 9 countries, under the glasses in 6 countries and over or under the glasses in 1 country. If dosimeter was used over the glasses, a reduction factor was used in 4 countries and it was not used in 4 countries.

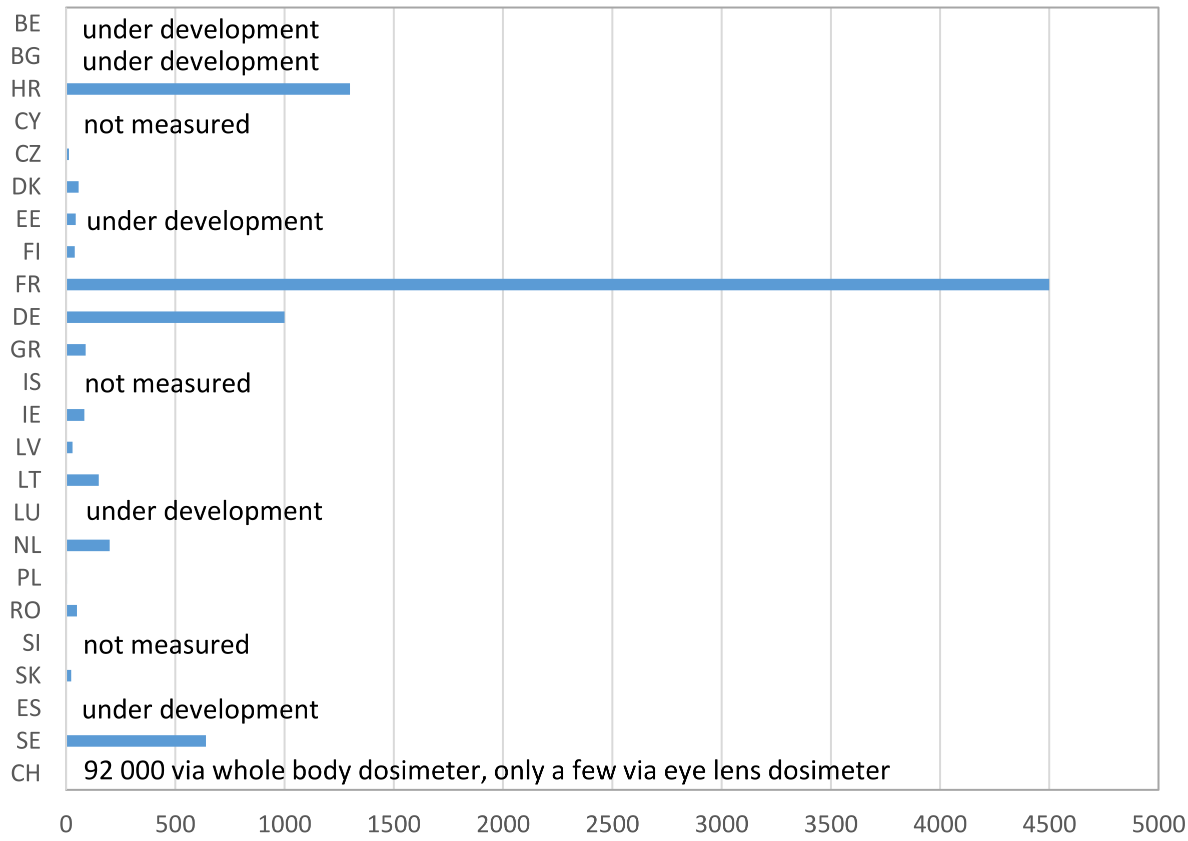

Figure 12 The number of monitored workers for eye lens doses.

The operational dose quantity measured to monitor the eye lens was $H_p(3)$ in 13 countries, $H_p(3)$ and $H_p(0.07)$ in 3 countries, and $H_p(3)$ and $H_p(10)$ in 2 countries. If eye lens doses were not measured, or measured by means of another quantity than $H_p(3)$, the doses were estimated in 5 countries and not estimated in 8 countries.

Exposure from neutrons to the eye lens was not considered in any of the 20 countries answering this question. Regulations regarding eye lens exposure have changed due to the recent implementation of the EU-BSS in 20 countries and in 2 countries the regulations have not changed. New dose limits for the lens of the eye were introduced in 17 countries. Out of these, in 7 countries the dose limit of the eye lens dose has lowered to 20 mSv/year and in 2 countries the dose limit of the eye lens dose has lowered to 100 mSv/5 years and simultaneously 50 mSv/year.

Following challenges regarding eye lens dosimetry have been expressed:

Implementation of new regulation

- Implementing of the new regulations smoothly in practice. To develop guidelines for operators how to better monitor eye lens exposure and what to do in case of over-exposure.
- Identification of work sector, practices and workers that might need to be monitored in view of new dose limit.

General

- Capturing doses for staff working in multiple locations.
- Ensuring staff wear eye-lens dosimeters properly and systematically – eye lens dosimeters are awkward to wear.

Dose assessment for eye lens doses

- Harmonization on the position of the eye lens dosimeter.
- To properly estimate the equivalent dose to the lens of the eye since the value depends strongly on the position of the dosimeter, its orientation regarding the source of radiation and whether is worn under or above the lead glasses, if worn. Inhomogeneous dose distribution (lateral and transparent shields). Eye-lens dosimeters may come out from under the glasses (when the glasses are worn), which may overestimate the eye-lens equivalent doses.
- The need to apply correction factors to take into account the use of protective garments, as well as the difference between the maximum dose area and the location of the dosimeter.
- How to consider measurement by means of another quantity than $H_p(3)$. Eye lens dosimeters are typically approved only for photons, and not for beta and neutron radiations; this is a particular concern and challenge expressed mainly by nuclear regulators.

Technological development

- Development of new types of personal dosimeters, modelling of expected personal doses in model situations (Monte Carlo calculation), including neutron fields.

Table 1 Position of the eye dosimeter.

Position of the eye dosimeter	No. of countries
On the forehead or in the corner of eye	4
In corner of the eye	3
On the forehead, above the eye closest to the radiation source	1
On the forehead, in corner of the eye or fixed on a full-face screen	1
On trunk	1
At the neck area, on top of protective apron	1
In corner of the eye, on lead glasses and also on collar	1
In corner of the eye or near the neck above the apron	1
On the side of eyeglasses or on a head band	1
Where the highest exposure is	1
As close to the eye as possible	1

3.2.8 Aircrew exposure

Fifteen out of 24 countries provided information regarding monitoring of aircrew personnel with respect to cosmic radiation. The other countries do not monitor or at least did not provide data. The numbers of monitored persons range from 400 up to 42.000 people per country.

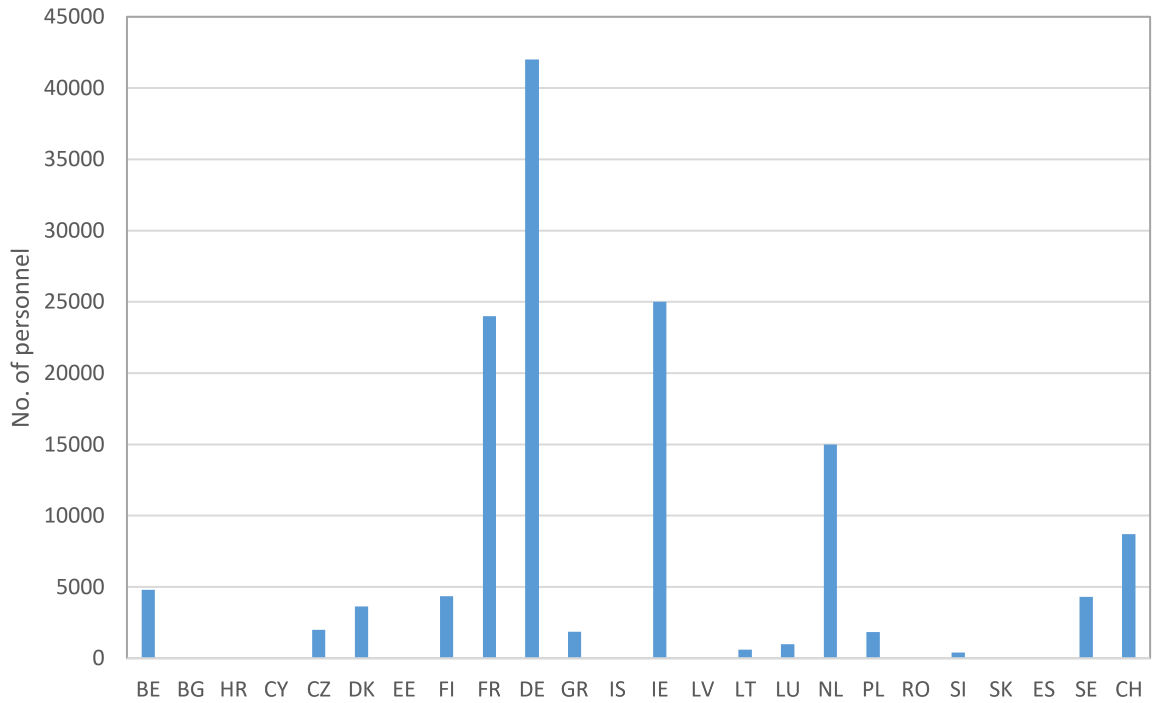

Figure 13 The number of aircrew personnel monitored for cosmic radiation.

In all cases, the occupational dose is calculated by computer programs. The most common program is CARI, which is used in 12 countries. Other programs, i.e., FREE, EPCARD, SIEVERT, PC-AIRE, PANDOCA, FAA, GLOBALOG and FAA are only used by a few countries.

The survey revealed that the quality control of the dose calculation, where monitoring is performed, is mainly supervised by competent authorities rather than by aircraft companies or dosimetry service providers. However, the standards to ensure a quality control vary greatly from country to country.

Regarding the legal requirements for dose assessment of aircrew personnel, the most countries are using the criteria that the dose assessment is mandatory when the annual dose of the aircrew member can exceed 1 mSv per year. Only a few countries are linking the obligation for dose assessment to the flight altitude of the aircraft.

The dose criteria (dose limits) for aircrew personnel are mainly 1 mSv/year for the beginning of monitoring and 20 mSv/year as a dose limit, which are in general the dose limits for other occupational exposed persons. In some countries there is also a reference level of 6 mSv/year.

Following challenges regarding aircrew monitoring have been expressed:

Dose assessment and quality control

- The development and application of dose assessment methodology for aircrew personnel
- Majority of national airflights are below 8000 m so we still have no big problems with dosimetric data. The real challenge is that there are no experienced experts in dose assessment in this area of dosimetry and the regulatory body has no experience in this field and needs to strengthen the competences in order to establish the efficient monitoring system
- To ensure the quality control of the dose calculation program
- "Definition on quality management system of air crew companies regarding to dose estimation methods (in cooperation with Civil Aviation Authority)
- In our country only the software CARI 6/6M is used, no request for use of other software has been made.

Reduction of aircrew doses

- There has been a very sharp increase in the collective effective dose of the aircrew personnel during the last years. Even during the covid-19 -year 2020, the most (70%) of the collective effective dose of all Finnish workers, was targeted at the aircrew personnel and except restricting the flying, we have no means to reduce their doses. We have no knowledge of the doses of the Finnish aircrew members flying under foreign airplane companies, which do not obey the Finnish legislation. Therefore, all aircrew members in our country do not have similar radiation protection as exposure limits vary from country to country."
- From 2016 to 2019, the number of workers exposed over 5 mSv has notably increased and needs to be studied (work in progress)

Scientific and regulatory issues

- Implementation of new National Dose Registry and relevant actions (dissemination training etc)
- Doses in our country for aviation crew is only registered for crew with a national id number. Crew members doses without Icelandic id number are therefore not registered. No cooperation with other countries regarding this.
- From a regulatory perspective, a National Dose Register is not yet available, hence air operators cannot comply with their reporting obligations as detailed in 10.10 above
- The current regulatory foundation appears to fully cover related subjects and corresponding challenges
- To implement new Directive requirements.
- Improve channels of information of concerned workers and of Occupational Health Physicians

3.2.9 Internal exposure (not including radon)

The number of workers monitored routinely for internal exposure ranges from 100.000 to only a few or even zero. In twelve countries the numbers range from a couple of hundred to a couple of thousands. Monitoring of workers following an unforeseen event is nearly always only a few with the exception of four countries where the numbers exceed some hundreds.

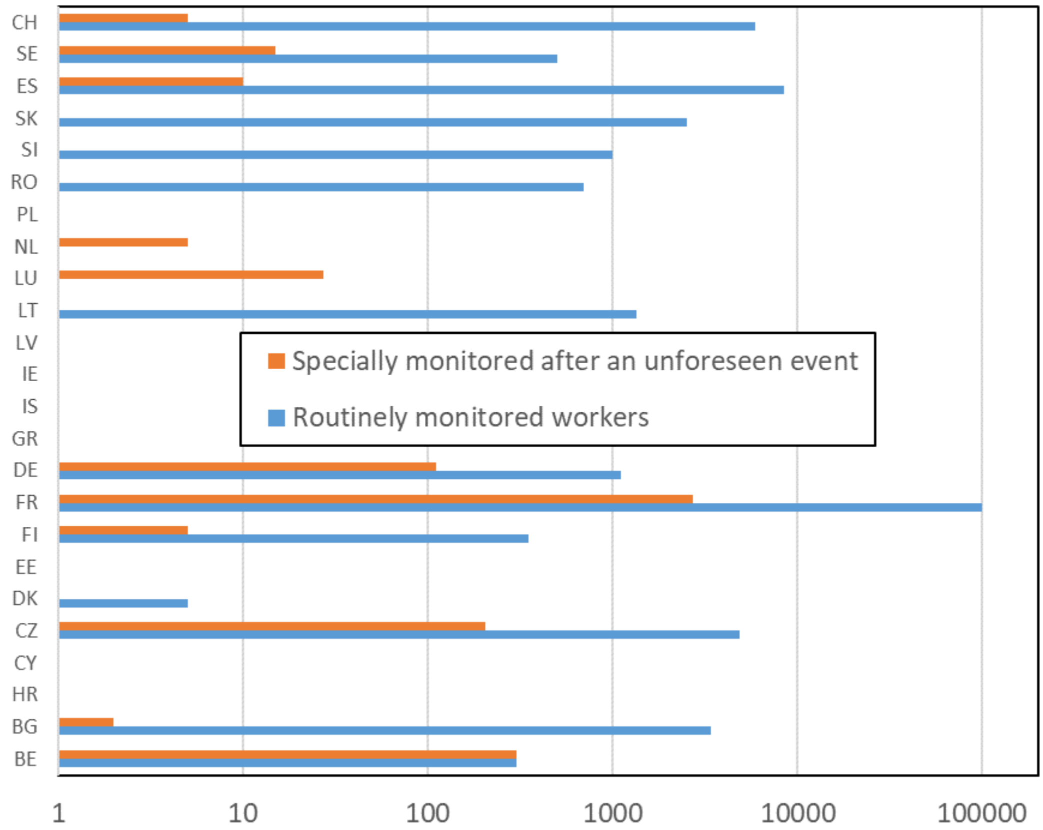

Figure 14 The number of monitored workers for internal exposure (not including radon).

Regulations to ensure quality and consistency of individual monitoring are put in place in fifteen countries. According to the information provided regulations vary greatly and include e.g.: requirements on lab accreditation, and ISO procedures, laboratory approval, requirements to follow EU and ICRP guidelines on internal dosimetry. Five countries have specific requirements on dose assessment to natural radionuclides.

Services provided in the country for monitoring and assessment of internal exposure is divers. Among those that provided information (17 out of 24); facilities for whole-body and thyroid measurement are available in nearly each country. In-vitro measurement, γ-spectrometry and LSC are also among the most common one. α-spectrometry is less common and inductively coupled plasma mass spectrometry is rare. Software for dose assessment is reported by 10 countries, where IMBA is most used followed by Taurus, IDEAS and AIDE. With the recent implementation of the EU-BSS regulation have changed in five countries. Mostly the changes are limited.

Following challenges regarding internal exposure have been expressed:

Dose assessment

- Estimating an internal dose is a complex science. As a result, dose estimates that fall somewhat outside the normal routine are often a challenge for the experts. Therefore, multidisciplinary knowledge is often needed to make an estimate of the internal dose as correct as possible.
- It is planned to compile a guide for holders of radiation practice licenses to estimate the internal exposure
- There are tables for calculation of committed effective doses upon inhalation and intakes of different radionuclides In the Regulation on radiation protection, but we have no practical guidelines for operators how to better monitor internal exposures and what to do in the event of an overdose

Maintaining an adequate infrastructure

- Lack of financing
- Development and application of in vitro measurement
- There is no commercial interest for laboratories to establish an internal dosimetry service. That is a problem for regulatory body also since the regulations can't force a laboratory to apply for an approval
- There is no routine internal dose assessment in the country. Some laboratories have in vitro measurements methods, but practical experience is very limited.
- For emergency response purposes there is a challenge in Sweden in that these types of measurements would be performed as part of the healthcare system by the regional councils, while the monitoring systems and laboratories mainly are maintained and financed by other organisations.

Technology development

- Emergency preparedness and communication in emergency situations. Development of quick in vitro analysis methods.
- Another challenge is the relatively short time frame available and number of persons potentially affected when responding to certain nuclear emergencies.
- Exploit of Monte Carlo calculation in model situations, development of a new phantom, development of new types of Fast Scan devices.

3.2.10 Radon

Seventeen out of 24 countries have a radon action plan (RAP) and for a further four countries the action plan is in development. Three countries indicated they do not have an action plan. Among those countries that provided details on the RAP every country with the exception of two adopted a reference level of 300 Bq/m^3. The two countries adopted a value of 200 and 100 Bq/m^3 respectively.

The number of workers that are under a programme for radon workplace monitoring varies much per country, with a maximum reported value of 2,800 workers. In most cases the numbers are much less (up to 200). It is also important to say that not always accurate information is available, or there is no monitoring at all. The number of workers under individual monitoring is generally lower with one country reporting 800 workers.

Sixteen countries reported that they have some system of quality control in place for monitoring and assessment of radon exposure; five countries do not have such quality control while three did not answer. Among the countries that have a quality control in place six countries explicitly stated that an ISO (17025) accreditation is required.

Information on the applicable radon DCC was provided by sixteen countries. Eight countries use the most recent ICRP recommendation of the ICRP-137. Other countries use the earlier recommendation from ICRP-65. A further two countries adopted the recommendations from ICRP-115. It is also important to note that also a couple of countries distinguish between indoor workplaces and underground mines.

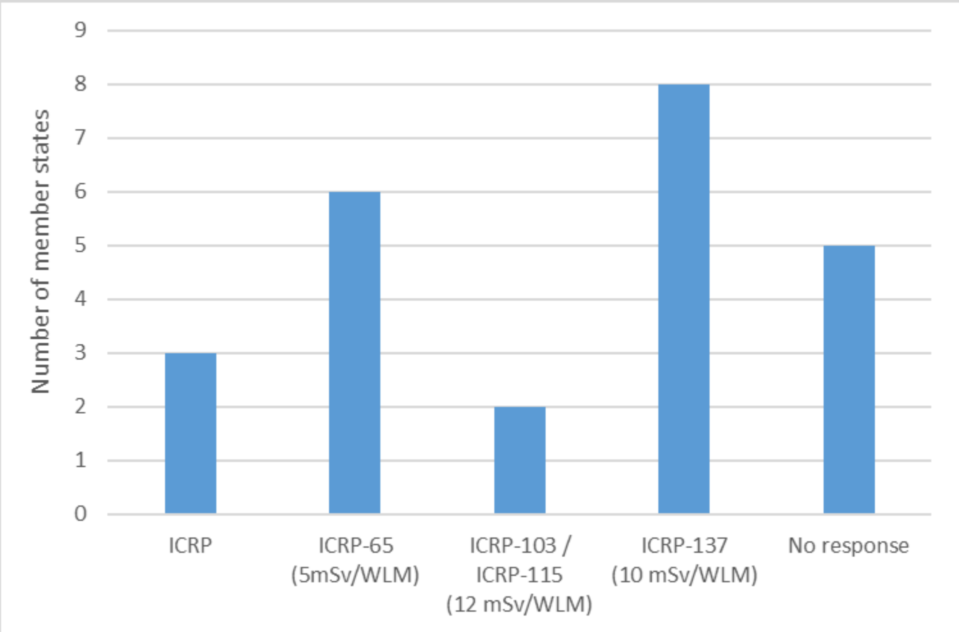

Figure 15 Adopted radon DCC's in the various countries.

Radon reporting in the dose register shows extensive variation. Some countries collect Rn dose, Rn concentration and/or any complementary information such as e.g., DCC and exposure time. Four countries do not collect any Rn information and six countries did not answer.

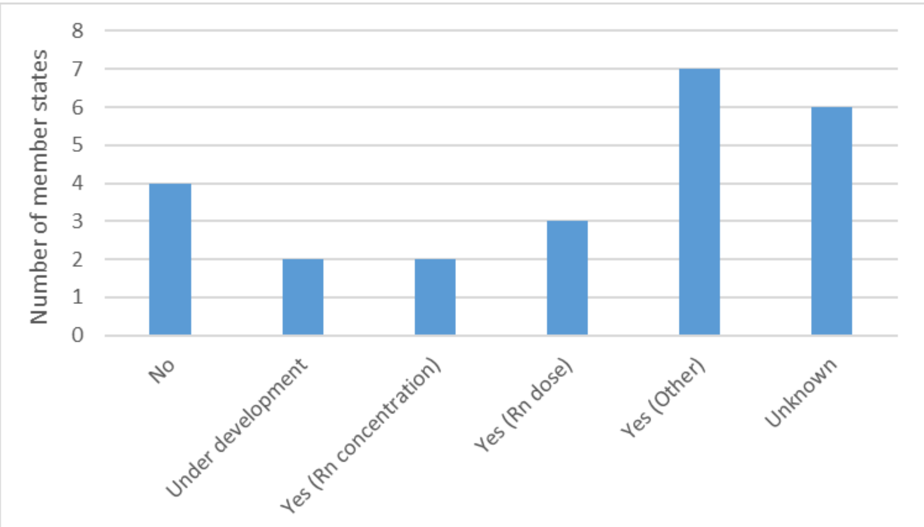

Figure 16 Registration of radon data in the national dose register.

Fourteen countries do consider radon exposure in determining the workers' total effective dose. However, in most situations this is only conditional, for example when concentrations exceed the reference level. In other cases, it is radon authorised practices only, or certain sectors such as NORM.

A detailed listing of all the challenges regarding radon exposure that have been expressed by the responders is provided below:

General

- The regulations are relatively new, and possible challenges may only be found during implementation into national legislation.
- The number of work places and workers concerned by radon exposure is unknown.
- Challenges are foreseen with the implementation of new regulations at workplaces, i.e., performing necessary measurements within time limits, taking measures against radon, if necessary, gaining acceptance for necessary measures.

Dose registry

- Procedures to include radon exposure in the dose registry.
- Collection and registration of radon dose in the National Dose Register.

Dose assessment

- The assessment of Rn doses of workers is under the progress, as well as integration with total effective dose.
- Deciding whether ICRP 137 DCC for radon dose assessment should be adopted in our country.
- Application of ICRP 137 Part 3 at workplaces with non-standard environmental conditions; protection of itinerary workers.
- There is a risk that in some show caves the number of hours an employee can work may be have to reduced or curtailed to ensure they do not exceed the dose limit. This is due to the new ICRP No 137-dose coefficient and the very high radon levels in some show caves.
- Regulatory perspective: Not all employers in our country have knowledge about legislation related to radon in workplaces, and therefore a large number of workplaces have not measured radon concentration yet.

Measurement and quality control

- The biggest practical challenge is that there is no approved TSOs for radon measurements in our country as well there are no experts in radon capable for providing advice on remedial methods. The building regulations do not include radon as a hazard so there is still no guidance for remediation and there are no building companies experienced in this area.
- Accurate assessment of radon exposure in mobile work, e.g., mines and subcontractors.
- Development of protocols for monitoring workplaces.
- At first the detection of radon exposure workers
- Determination & detection of the radon exposure of workers
- Authorisation of radon personal dosimetry services;
- Scientific perspective: Measurement methods for estimation of indoor radon concentration average value should have more solid scientific basis. For instance, to assure the number of measurement points needed for radon measurements in buildings in order to provide a sufficiently good assessment.

- To perform reliable measurements of radon concentrations in challenging environments such as with high humidity, with temperatures deviating considerably from normal temperatures, with high particle concentrations etc.

Awareness and acceptance

- Improving cooperation between competent authorities.
- The lack of awareness among employers of the risk of radon exposure and therefore there is a lack of understanding and commitment by some employers to address radon.
- Raising consciousness of workers and employers
- Information of the public together with raising awareness, identification of workplaces exposed to radon, consideration of the equilibrium factor
- Although knowledge about health effect of radon is quite high, there are still a large number of owners of one and two-family houses who have not yet measured radon concentration.

Other

- Thoron in underground workplaces and NORM industry.
- Developing models which describe radon concentrations as a function of different risk factors such as uranium content in soil, ground conditions, soil type, construction age etc.
- Almost all new buildings have been constructed using methods that highly restrict the inflow of ground radon, and therefore the indoor radon concentrations in new buildings in most cases are well below the national reference level 200 Bq/m^3. But nevertheless, it would be desirable to investigate how well the radon content is maintained at a low level after many years with the present construction methods.

4 Discussion

This section provides some analysis of the findings from survey. The observations are also in some cases linked with other (international/wider) developments in the field of radiation protection. The section provides, where possible, context to these findings, and may present issues that interconnect the individual topics.

4.1 Findings and observations

4.1.1 National dose register

The NDR's are or have recently experienced considerable changes. These are in part a result of the EU-BSS implementation, which has set new requirements on the (dose) information that must be registered. However, NDR's must also be compliant with the European GDPR, particularly as dose information is considered special personal data, due to its relation to health. This poses additional requirements on the organisation of the NDR such as implementation of a data protection policy, and continuous improvement to ensure the safe registration of dose information from exposed workers. This includes much better policies on risk of data loss, fraud and misuse from electronic data systems that can be exposed to e.g., malware attack.

The survey revealed that the collection of new quantities such as $H_p(3)$ as well as Radon (NORM) is posing challenges. This conclusion is also derived from the analysis of the current practise indicating considerable variation in the collection of the dose quantities; hence, the need for more guidance. The lack of coherent measurement practise, and the lack of quality standards adopted by the service providers is a major concern for the NDR's in countries with a limited number of exposed workers. Furthermore, most NDR's have reported in recent years a decline in number of workers, which makes the extended responsibilities of the NDR more challenging. Finally, it is important to iterate that there is a strong interest for sharing aggregated dose information under the umbrella of HERCA.

4.1.2 Radiation passbook

The survey revealed that radiation passport is pursued in most participating countries. Regarding the radiation passbook and the new EU-BSS, 10 countries answered positive that they have made changes in regulations in order to implement the directive. It is suggested by some respondents that all countries should incorporate the radiation passbook in their legislation. The radiation passbook in the participating countries is either hardcopy (60%) or electronic (30%). It is noted that the electronic version of radiation passbook may be more useful in the future. Besides, the electronic radiation passbook could be associated with the national dose registry and might be part of it.

Concerning the challenges, answered by the respondents, 50% of the comments refer to the necessity for an electronic radiation passbook using cloud technology, mobile applications, etc. They also remarked the need for a common electronic radiation passbook all over Europe in accordance with the European directive. In this way the individual monitoring system for the outside workers in each country will become faster, cheaper and modernised. This tool has to be simple and user friendly. For instance, it would be useful for the employers to have an electronic access to the passbook where they could fill in the required data. This would eliminate the chances of the passbooks getting lost.

A challenging issue concerning electronic radiation passbook is privacy and data protection. As an electronic tool it has to conform with data security techniques and the European General Data Protection Regulation (GDPR).

Another challenge for the radiation passbook, mentioned by respondents, is its promotion and information of stakeholders (organisations, employers, workers, etc.). Dissemination events would be helpful in this direction. Non-conformities with radiation passport processes are another challenge. Even though it is not very common, in some cases passbooks are not returned for over a decade or reported lost. It is also important to continue communication and exchange of good practices in order to achieve better harmonisation and coherence among the different national processes of radiologic follow-up for the outside workers crossing the boundaries.

4.1.3 Recognised dosimetry services

It appears from the survey that there are two major issues with regards to the recognised dosimetry services. The first is a development to increase quality standards of the dosimetry service, with a total of five countries that reported that they recently or in the near future will require an ISO17025 accreditation as part of the approval. Traditionally, dosimetry services are linked with or part of the national research institutes, and a strong focus on the national market. Recently, there is a shift towards larger dosimetry services that are operating internationally. This development can change the national landscape of dosimetry services, with some established institutions that will stop their activities. Larger organisations might be better positioned to innovate their product range and provide state-of-the-art quality standards. Simultaneously, some HERCA members have indicated their concern on the availability of an adequate infrastructure, such as recognised dosimetry services, monitoring facilities and quality standards. These concerns are most prominent for the monitoring of internal exposure and radon, due to the limited number of workers involved, and the lack of a sustainable business.

From the survey it is concluded that the dosimetry services are not a priority topic. It should also be considered that issues, and particular those of a scientific nature, are better addressed through involvement of the dosimetry services. A well-known platform where many of these activities are researched is the European Dosimetry Network EURADOS. A possible topic for future work of the ODCRR is to take a regulatory view on the scientific studies by e.g., EURADOS.

4.1.4 Whole body dosimetry

Regarding the whole-body dosimetry considerable challenges are highlighted and described in Section 3.2.5. These include changes in operational quantities by ICRP or in protection quantities by ICRP, which are seen as a practical problem. In addition, practical questions regarding the use of protection garments, the use of two dosimeters, position of dosimeters (e.g., under or above apron), the correct use of algorithms, are seen to be important. Other challenges are related to the new technological developments. These developments are emerging quite quickly, and the regulatory framework may have to be adapted to take this technical evolution into account. It is concluded that some guidance on the various challenges based on expert discussions in the HERCA network would be welcomed.

4.1.5 Extremities/skin dosimetry

The doses to the extremities of exposed workers are measured and recorded in dose registers in most European countries. The main challenges relate to the estimation of realistic extremity doses, taking into account the placement of dosimeters, protective garments and the direction of radiation, as well as procedures for estimating skin doses in case of contamination, and the development of appropriate dosimeters.

The ICRP recalls the need to use real measured doses rather than calculated values. This is not always straightforward when aiming to measure the dose to the most exposed area of the skin, but it may not be possible to place the dosemeter in that area. Similarly, the use of protective garments may distort the measurement result. For these reasons, the measured dose may not always reflect the actual dose. Therefore, the user of the dosemeter must know how to position the dosemeter correctly, determination of the dose must take the above into account and the authorities must be able to provide appropriate instructions for recording doses.

Another major challenge at present is the measurement of beta radiation, as no suitable dosemeters with appropriate calibration are available. The development of measurement methods is therefore necessary to determine doses in the way that the ICRP is calling for.

Skin contamination situations are relatively few but may involve significant skin exposure. In skin contamination situations, dose determination is difficult and can be done in a number of different ways. There is a need for guidance on dose determination and selection of an appropriate method.

4.1.6 Eye lens dosimetry

Workers' eye lens doses are measured and recorded in dose registers in more than half of European countries. The main challenges relate to the implementation of the new regulations and the estimation of realistic eye lens doses, taking into account the positioning of the dosemeter, protective eye wear and the direction of radiation.

The ICRP encourages the use of actual measured doses rather than calculated values. However, it is not always possible to place the dosemeter where it best reflects the dose to the lens of the eye. The position of the dosemeter and the direction of radiation cause also a significant influence on the measurement result. In addition, there are many different types of protective eye wear in use, making it very difficult to determine the actual dose. Guidance from the authorities on acceptable procedures for measuring dose, taking into account protective eye wear and determining dose would be welcome. Eye dosemeters are also somewhat uncomfortable to use and, especially in nuclear facilities, can pose a risk of loose particles falling into inappropriate places. The development of dosemeters is therefore also needed.

Another challenge is the smooth implementation of the new provisions in practice. Both experts and authorities should develop guidance for radiation workers on how to better monitor eye lens exposure, how to keep exposure at acceptable levels, and what to do in case of overdoses. It would be important to identify work tasks, practices and workers who may need to be monitored because of the new dose limit.

4.1.7 Aircrew exposure

The survey revealed that the regulatory and dosimetry standards regarding air crew monitoring vary significantly between countries. While a few countries do not seem to carry out any monitoring, other countries have established regulations and procedures regarding monitoring which however differ quite much. On the one hand, the air crew doses are calculated by comparable computer programs in all respective countries. But on the other hand, the quality control of these programs and the organisation of supervision vary greatly from country to country.

Another regulatory problem mentioned in the survey is related to the fact that many air crew members are flying under foreign airplane companies. Air crew members may be subject to different regulations and standards depending on the country where the flight originates or where the airline is based. This can create confusion and inconsistency in terms of monitoring and managing air crew exposure to cosmic radiation, especially when it comes to tracking and managing the exposure of air crew members who fly for multiple airlines or work for companies based in different countries.

In the absence of clear international standards for air crew dosimetry, it can be challenging for governments, airlines, and air crew members themselves to ensure that appropriate measures are being taken to minimize exposure to cosmic radiation. This highlights the need for international cooperation and collaboration to establish consistent regulations and standards in this area.

Moreover, the dose criteria and dose limits for aircrew personnel (including pregnant personnel) vary between countries. There are no universally accepted dose criteria for air crew when dose assessment gets mandatory. Different countries have their own regulations and standards in place. This picture is even more pronounced when looking at the global level, which was recently presented by the latest UNSCEAR report on occupational exposures. This report reveals that there are worldwide many countries, as e. g. the United States, where no official dose limit for air crew is established and where consequently no monitoring is performed.

Overall, the situation regarding air crew dosimetry when comparing different countries is complex, with a range of technical, logistical, and regulatory challenges that need to be addressed in order to achieve international harmonisation, comparable conditions and the elimination of bureaucratic obstacles.

4.1.8 Internal exposure (not Rn)

It is recognised that the determination of occupational dose from internal exposure can be challenging, demanding for adequate monitoring, sampling and detection techniques. In addition, some kind of computation is required to determine the effective committed dose. Protocols and guidelines as well as software tool for dose assessment are available. Nevertheless, they require considerable expertise and substantial measurement equipment. For this reason, some countries have established measures put in place to ensure quality of every aspect involved, such as: lab accreditation, and ISO procedures, laboratory approval, and requirements to follow EU and ICRP guidelines. Nevertheless, the number of workers requiring such kind of assessment is in many countries well below a 100 per year.

Consequently, the main challenge for many countries is to ensure a minimum infrastructure necessary for monitoring and assessment of internal exposure. This is also shown in the limited availability of services for in-vivo and in-vitro measurement in some countries. Among the countries with an extensive workers monitoring programme there is a demand for addressing various challenges in monitoring and assessment of internal exposure. This includes for example emergency situations, which are considered technically challenging.

4.1.9 Radon and thoron exposure

There are a limited number of countries with extensive experience on monitoring the occupational dose from radon exposure. These countries also have an adequate infrastructure that provides services on radon monitoring and dose assessment with an agreed level of quality. Nevertheless, for many countries this area of occupational exposure is new resulting in many challenges on many issues. Among the most important these include a concern on the lack of appropriate infrastructure, such as a lack of service providers, quality standards and established procedures for monitoring and evaluation of the dose. These findings suggest that some countries would clearly benefit from guidance and best-practise in the field of radon monitoring and dose assessment.

A total of six countries indicate that they do not register dose information on radon exposure in their national dose register, while among those that do there is wide variation in the specific information that is collected. Some countries register radon concentrations, while other only radon dose and any kind of combinations. Similarly, the adopted radon DCC among the different countries differs widely. While most countries have adopted the most recent ICRP recommendation of the ICRP-137, many countries also refer to earlier ICRP recommendation using a different radon DCC. Another relevant issue is the summing of effective dose from external and radon exposure, which appears to be differently applied across the EU owning to the wide variation in radon dose assessment and registration of dose information. As many of the issues mentioned under this paragraph are of direct relevance to the NDR's they could provide for a future activity under the HERCA ODCRR. Such topic should investigate recommendations, quality assurance and practical guidance on the collection and registration of dose information from occupational radon exposure, taking due consideration of national challenges in radon monitoring and dose assessment. More specific such topic should cover: e.g., information to be monitored and collected, quality standards that enable comparable/known level of dose uncertainty.

Considering the lack of information on occupational radon exposure, the HERCA ODCRR should consider a future activity to collect aggregated radon dose information from the HERCA members. This should then be followed by an analysis to develop some understanding on the type of workplaces and industries and their risk to radon exposure. Such exercise could be facilitated using the ESOREX platform hosted by IRSN.

Occupational exposure to thoron is considered to be relevant in some specific circumstances according to e.g., UNSCEAR. Such circumstances typically include thoron in underground workplaces and specific NORM industries dealing with materials that are high in Th-232 content. As it appears from the findings of the questionnaire, present concerns are by and large related to radon; however, thoron might become more relevant in future when most challenges on radon exposure are addressed.

4.2 Suggested items for future work

An overview of the items for future ODCRR activities proposed by respondents is presented in the table below. The items are obtained from summarising the suggestions raised by the individual respondents, but also as an outcome from the analysis of the current practise. It is important to state that this is an outcome of the survey, and not the formal request for future work of the ODCRR network. The proposal for future work is formulated in Section 5.2.

Table 2 Summary of the suggested items for future ODCRR activities, based on the ideas from the individual respondents.

Topics	Items for future ODCRR activities
National dose register	- HERCA network provide platform for discussing questions in the field of NDR; - Harmonisation of collected dose information, and benchmarking against other EU MS.
Radiation passbook	- Work towards a harmonised approach for electronic passbooks; - To optimise/harmonize the content of the radiation passbook; - Passbook that considers data protection issues by limiting the sensitive information to an absolute minimum.
Recognised dosimetry services	- Guidance on dosimetry measurement and corrections (such as lead apron). Take regulatory view on scientific studies by e.g., EURADOS.
Whole body dosimetry	- Guideline document (various topics) based on expert discussion in the HERCA network, for submission on the HERCA website.
Extremities/skin dosimetry	- Guidance on estimating realistic extremity doses and recording doses; - Guidance on procedures for estimating skin doses in contamination cases and selection of the appropriate method for dose estimations - To follow development on new technologies/methods especially for beta radiation.
Eye lens dosimetry	- Recommendation on how to identify workers who may need to be monitored because of the new dose limit.
Aircrew exposure	- Guideline, recommendations on international standards for air crew dosimetry and monitoring.
Internal exposure (not Rn)	- Recommendations on internal dose assessment in case of emergency, with adequate protocols/methods; - Recommendations for monitoring in case of limited equipment.
Radon	- Establish robust dose assessment / monitor and collection of data - Provide guidance on measurement and assessment that enable comparable or known levels of dose uncertainty.

5 Conclusions

5.1 General conclusions

A comprehensive survey on the subject of occupational dose collection registration and reporting was carried out by the HERCA ODCRR network. The large response to the questionnaire indicated considerable interest among HERCA countries in the field of occupational exposure. Nearly all topics received a score of more than 3.5 (out of 5) when asked if the topic should be considered for future work. The topics radon and eye lens received a score of nearly 4.5. These scores were complemented with a comprehensive list of suggestions for future work items. The suggestions reveal that guidance on scientific and regulatory aspects of occupational dose monitoring and collection would be welcomed. In addition, there is a strong interest among the HERCA members for sharing aggregated dose information under the umbrella of HERCA.

The survey has shown that the number of monitored workers in the different EU countries varies by around three orders of magnitude for all types of exposure. The number of monitored workers has significant impact on the available dosimetry infrastructure in the country and therefore, the challenges and needs by the HERCA members vary considerably.

The survey revealed that around 50% of the countries have changed their regulations regarding the national dose register due to the recent implementation of the EU-BSS. These changes were related to the content of the register and the allocation of responsibilities to those involved in transferring dose information. Among these countries many of them are presently working on the modernisation of their NDR such as digitisation and automation of the dose collection, as well as improving the completeness of the dose records. The radiation passbook is a key responsibility of the NDR's and the format of the passbook varies greatly, there are increasing national initiatives towards an electronic passbook, raising the question for some best practise in this area.

For the approval of the dosimetry services multiple countries have recently included ISO17025 accreditation as a requirement. It was also noted that concerns are expressed on the availability of dosimetry services and the implementation of adequate measures to ensure the quality of individual monitoring. These concerns are most prominent for the monitoring of internal exposure and radon, due to the limited number of workers involved, and the lack of a sustainable business for these types of services.

Regarding the monitoring of extremity dose, $H_p(0.07)$ is measured and collected in nearly all countries. However, the position of the dosimeter, the use of multiple dosemeters and its location below or under the protective garments varies. Furthermore, it still remains a challenge to obtain a realistic dose estimate with finger dosemeters when exposed to beta radiation. Regarding the monitoring of the workers' eye lens similar variations in measurement practice are found. In addition, also the eye lens doses is estimated in some countries using the results from other operational dose quantities. Another challenge in the monitoring of the eye lens is the smooth implementation of the new provisions in practice. Both experts and authorities should develop guidance for radiation workers on how to better monitor eye lens exposure, how to keep exposure at acceptable levels, and what to do in case of over-exposure.

The occupational dose for aircrew is calculated by computer programs in all cases. Furthermore, the survey revealed that the regulatory and dosimetry standards regarding air crew monitoring vary significantly between countries. While a few countries do not seem to carry out any monitoring, other countries have established regulations and procedures regarding monitoring which however differ quite much. Another regulatory problem mentioned in the survey is related to the fact that many air crew members are flying under foreign airplane companies. Air crew members may be subject to different regulations and standards depending on the country where the flight originates or where the airline is based.

For the monitoring of internal dose, the main challenge for many countries is to ensure a minimum infrastructure necessary for monitoring and assessment of internal exposure. This is also shown in the limited availability of services for in-vivo and in-vitro measurement in some countries. Among the countries with an extensive workers monitoring programme there is a demand for tackling technical challenges e.g., in monitoring emergency situations.

For many countries radon monitoring is new resulting in many challenges on many issues. These include a concern on the lack of appropriate infrastructure, such as a lack of service providers, quality standards and established procedures for monitoring and evaluation of the dose. In addition, it is observed that there is no consistency in the collected information from radon exposure by the NDR's.

5.2 Recommendations for future work

To deliver on all of the suggested items for future work is a major task and will require extensive knowledge in multiple areas such as dosimetry, individual monitoring, dose collection, industrial practise and regulation. Therefore, the future work of the network should take due consideration of already ongoing initiatives in the field of occupational exposure, as well as a clear understanding on the core competences of the network members and the networks mandate. The primary responsibility of the network members is the operation of their NDR. For this reason, the network should focus on issues directly related to the improve the collection, recording and reporting of the dose information. However, it should also be noted that the NDRs operate a comprehensive and unique database with information from individual dose monitoring, often covering a history of multiple decades. Therefore, the network should also consider the collection and interpretation of aggregated data on occupational dose exposure to facilitate the development of necessary (regulatory) guidance in other HERCA Working Groups. Given the above considerations, the ODCRR network suggests that its future work should focus on the following topics:

- Use the network as a platform allowing people in charge of the national dose register in their countries to exchange on good practices, encountered difficulties, and experiences learned in the context of the operation of the NDR's. The network could focus on present practise in radon dose collection, deal with the exchange of data between countries for the follow-up of cross-border outside workers and digitization, IT security, digital dosimetry and data protection.
- From this exchange the HERCA network could obtain overviews and identify best practise in the field of dose collection, recording and reporting.
- As part of this exchange aggregated dose information will be collected which will facilitate the activities in other HERCA WG's. For the collection of the aggregated data the European platform for Occupational Radiation Exposure (ESOREX) platform would be the preferred platform.