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The work programme of EURADOS on internal and external dosimetry

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Abstract–Since the early 1980s, the European Radiation Dosimetry Group (EURADOS) has been maintaining a network of institutions interested in the dosimetry of ionising radiation. As of 2017, this network includes more than 70 institutions (research centres, dosimetry services, university institutes, etc.), and the EURADOS database lists more than 500 scientists who contribute to the EURADOS mission, which is to promote research and technical development in dosimetry and its implementation into practice, and to contribute to harmonisation of dosimetry in Europe and its conformance with international practices. The EURADOS working programme is organised into eight working groups dealing with environmental, computational, internal, and retrospective dosimetry; dosimetry in medical imaging; dosimetry in radiotherapy; dosimetry in high-energy radiation fields; and harmonisation of individual monitoring. Results are published as freely available EURADOS reports and in the peer-reviewed scientific literature. Moreover, EURADOS organises winter schools and training courses on various aspects relevant for radiation dosimetry, and formulates the strategic research needs in dosimetry important for Europe. This paper gives an overview on the most important EURADOS activities. More details can be found at www.eurados.org.

This paper does not necessarily reflect the views of the International Commission on Radiological Protection.

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1. INTRODUCTION

The European Radiation Dosimetry Group (EURADOS) is a network of institutions interested in the dosimetry of ionising radiation. As of 2017, the network includes more than 70 institutional members from approximately 30 countries, and the EURADOS database lists more than 500 scientists who contribute to the EURADOS mission. The network supports research and technical development in the field of dosimetry of ionising radiation, and promotes harmonisation of dosimetric procedures across Europe and their conformance with international practices. Moreover, EURADOS supports a variety of actions in training and education, and organises, for example, 1-day winter schools on relevant topics, training courses in dosimetric techniques such as the use of voxel phantoms, and courses on European technical recommendations in the field of individual monitoring. A short overview on the current status was summarised recently (Rühm and Schuhmacher, 2017).

The present paper describes the work programme of the eight working groups that are currently active. These include seven working groups dealing with scientific aspects in environmental, computational, internal, and retrospective dosimetry; dosimetry in medical imaging; dosimetry in radiotherapy; and dosimetry in high-energy radiation fields; and one working group focusing on the harmonisation of individual monitoring across Europe and even beyond. In the following, the working programme and results obtained are summarised for each of these working groups.

2. EURADOS SCIENTIFIC WORK PROGRAMME

2.1. Environmental dosimetry

The aim of Working Group 3 (Environmental Dosimetry) is the correct measurement of the ambient dose equivalent, the ambient dose equivalent rate, and activity concentrations caused by different release scenarios, such as routine emissions, nuclear accidents, and terrorist attacks. With this objective in mind, Working Group 3 is intended to provide: (1) metrological support of the harmonisation process of early warning dosimetry network systems in Europe; (2) development of methods for environmental dosimetry; (3) organisation of comparison programmes; (4) investigation of the use of gamma-ray spectrometry systems for environmental radiation monitoring, including drones; (5) publication of technical recommendations, peer review papers, and EURADOS reports; and (6) stimulation of cooperation, data exchange platforms, national authorities, research projects, and others.

According to different metrological procedures and increased interest in spectrodosimetric systems (e.g. based on $LaBr_3$, $CeBr_3$, SrI_2, and CZT), Working Group 3 has recently founded two subgroups, namely spectrometry systems for environmental dosimetry (S1) and passive environmental dosimetry (S2).

The activities of S1 are grouped into four subject areas, as shown below.

(1) Comparison of methods for calculating ambient dose equivalent rates from photon spectra. This has been carried out in collaboration with the MetroERM project (Metrology for early warning networks – http://earlywarning-emrp.eu/), and results have been published (e.g. Camp and Vargas, 2014; Dombrowski, 2014; Vargas et al., 2017).
(2) Comparison of automatic tools for spectra analysis, such as full spectra analysis and peak-based nuclide identification.
(3) Harmonisation and uncertainty analysis of dose rate meters and spectrometric monitors in collaboration with the CONFIDENCE project (COping with uNcertainties For Improved modelling and DEcision making in Nuclear emergenCiEs – https://portal.iket.kit.edu/CONFIDENCE/) and the real-time radiological data platform EURDEP (https://eurdep.jrc.ec.europa.eu/Basic/Pages/Public/Home/).
(4) Development of mobile spectrometric monitors. The aim of this subject is to develop, test, and validate metrologically traceable systems and methods for remote measurements of ambient dose equivalent rates and activity concentrations using unmanned aerial vehicles commonly named 'drones', with spectrometry systems mounted on them. This activity will be carried out in the framework of the European project 'Preparedness' (Metrology for mobile detection of ionising radiation following a nuclear or radiological incident – https://www.euramet.org/).

S2 compares and studies passive environmental detectors. Results of the most recent comparison were published by Dombrowski et al. (2017) and Duch et al. (2017). Currently, the first EURADOS comparison (IC2017calm) of calibration methods for passive area dosimeters is being performed. In this campaign, a set of area dosimeters from Karlsruhe Institute of Technology (Germany) was sent to each of the participating irradiation facilities to verify laboratory calibration procedures. Analysis of the results is currently in progress.

2.2. Computational dosimetry

Working Group 6 (Computational Dosimetry) promotes research and best practice in computational methods applied to radiation protection and dosimetry. Monte Carlo (MC) methods dominate the work programme as the technique is in widespread use to assist with almost all areas of dosimetry. However, deterministic and unfolding methods are still investigated as these are also important tools.

Originally, Working Group 6 included most of the scientists working in this area in Europe, using bespoke codes developed within their own laboratory. Now, well-benchmarked MC codes that allow for transportation of a wide range of particles are widely available, and the use of bespoke codes is restricted to the most specialist of problems. Most EURADOS working groups perform tasks that require MC methods, so Working Group 6 collaborates closely with several other working groups on joint tasks. The computational dosimetry work programme can be broadly divided into three types of task: research into the best methods available; intercomparisons to test how well the methods are applied; and training activities.

Research activities are directed at the biggest challenges for computational methods: the smallest scales, the highest energies, and the mathematical description of humans. Modelling of particles and their energy deposition on the subcellular scale is of fundamental importance to the understanding of the biological effects of radiation. This is an area where there is much uncertainty on particle transport and cross-sections for interactions, because initial high-energy particles result in many lower-energy electrons and photons that are responsible for the ionisations that cause DNA damage. Working Group 6 is investigating these aspects of dose deposition via collaborative research (Alexander et al., 2015; Bueno et al., 2015; Dressel et al., 2017; Villagrasa et al., 2017; Dressel et al., 2018). For high energies, there are similar problems for MC methods as cross-section data are largely missing, and nuclear models are applied to simulate scattering and secondary particle generation. Work in collaboration with Working Group 11 has shown that the model selection has a large influence on the computed results (Rühm et al., 2014), which has led to the development of a benchmarking task for high-energy calculations. Modelling of energy deposition in voxel phantoms has led to improved understanding of the link between fortuitous dosimeter readings, radiation exposure, and potential for tissue reactions (Eakins and Kouroukla, 2015).

Whilst MC methods are well benchmarked, their use is still subject to significant user influence. Intercomparisons have been used to demonstrate that, even for relatively simple problems, users can get results that are in error by several orders of magnitude (Gualdrini et al., 2008). These problems can result from minor mathematical errors, but they can also be caused by erroneous specification of the problem or the use of inappropriate physics. Intercomparisons that are underway divide broadly into two categories: for expert users, where EURADOS members try to understand best practice and converge on optimised results; and open intercomparisons to test the application of computational methods by the wider community. The first category includes nanodosimetric studies and the high energies seen around accelerators and in cosmic rays; a nanodosimetric intercomparison is underway that will provide results on converged solutions for energy deposition at the subcellular and DNA scales (Villagrasa et al., 2018). The second category includes modelling of dosimeters, calibration rooms, linear accelerators, simplified biological models, neutron spectrum unfolding, and voxelised phantoms; recently, results from an intercomparison of medical linear accelerators were published (Caccia et al., 2017), and currently results from a neutron spectrum unfolding exercise are being analysed, and an intercomparison of implementation of the ICRP reference phantoms is due to be launched shortly.

Linked to the intercomparisons, training in the use of MC methods forms a central part of the work programme. Regular training schools are held on voxel phantom development, implementation, and usage. This is now being extended to include a school on best practice in the use of MC methods for external dosimetry.

2.3. Internal dosimetry

Working Group 7 (Internal Dosimetry) deals with the assessment of doses due to internal exposures. The challenge is to cover all relevant topics from radionuclide monitoring to dose evaluation to identify gaps that need further development, coordinate research, promote harmonisation, and disseminate results and knowledge. The aim is to provide tools and methodologies allowing for a reliable dose assessment for workers and members of the public (adults and children), and for different internal exposure scenarios such as occupational exposures, emergency situations, nuclear medicine, and others. One of the priorities of Working Group 7 is to establish a formal collaboration with ICRP Committee 2, especially with respect to ICRP biokinetic models and application of new worker dose coefficients. Currently, Task Group 7.2 of Working Group 7 is involved in the elaboration of a guidance document for application of the new occupational intakes of radionuclides (OIR) publications from ICRP. The OIR series updates the methodology of internal dose assessment according to ICRP's 2007 Recommendations (ICRP, 2007). Task Group 7.3 is dealing with the development of a biokinetic model of DTPA therapy including collaborators from France, Germany, and the USA. Another topic of common interest is internal dosimetry in emergency scenarios (Task Group 7.4) (Lopez et al., 2016). Members of Working Group 7 have been involved in research projects such as CAThyMARA 'Child and Adult Thyroid Monitoring After Reactor Accident' (EC FP7, 2016–2017) and CONFIDENCE, which is a collaboration of the four European platforms on radiological protection – NERIS, EURADOS, MELODI, and ALLIANCE – in the frame of the CONCERT action (EC H2020, 2017–2019).

Important outcomes of Working Group 7 are the IDEAS Guidelines (V2) for the 'Estimation of Committed Doses from Incorporation Monitoring Data' (Task Group 7.1, Castellani et al., 2016) and the 'Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides' (Task Group 7.6, Etherington et al., 2016, 2018). A new initiative by Working Group 7 is the ICIDOSE 2017 intercomparison for the calculation of internal doses by interpreting monitoring data of four case studies, using the IDEAS Guidelines and the Technical Recommendations as reference documents. A further important issue is how to deal with uncertainties in internal dose assessments. To address this topic, Task Group 7.5 launched an exercise in 2017 including evaluation of lifetime doses for three workers occupationally exposed to uranium (Davesne et al., 2017). This task group has also been involved in studies on uncertainties in epidemiology and risk assessment for internal emitters.

Collaboration of Working Group 7 and Working Group 6 is traditionally close in terms of the application of MC methods and voxel phantoms for in-vivo calibration of body counters (Task Group 7.4), resulting in a number of intercomparison exercises and publications (Nogueira et al., 2015; Vrba et al., 2015; Breustedt et al., 2016), and on microdosimetric studies of internal emitters (Task Group 7.7), especially for nuclear medicine and radiotherapy applications. Task Group 7.8 is collaborating with Working Group 10 on the application of biodosimetric techniques in scenarios involving accidental internal exposures. The challenge here is to link dose values obtained by applying retrospective dosimetric methods with internal dose evaluations obtained from bioassay monitoring data. The analysis of data for 10 case scenarios including exposures at the Goiania accident, Semipalatinsk, Mayak, and others is under discussion and will be presented in a publication in 2018.

Finally, Working Group 7 is involved in training actions such as the 10th EURADOS Winter School on Internal Dosimetry for Radiation Protection and Medicine during the 2017 Annual Meeting, the preparation of a training course based on the EC Technical Recommendations in 2018, and the organisation (with Working Group 6) of a CONCERT course on ‘Application of MC Methods for Dosimetry of Ionizing Radiation’ (which was held in March 2018). The work of Working Group 7 is described in more detail in another paper in this issue (Breustedt et al., 2018).

2.4. Dosimetry in radiotherapy

The objective of Working Group 9 (Radiation Dosimetry in Radiotherapy) is to promote the development of dosimetry in photon and hadron (currently proton) radiotherapy using existing and potential dosimeters and dosimetric techniques. These include the use of passive detectors (e.g. those based on thermoluminescence (TL), optically stimulated luminescence (OSL), and radiophotoluminescence (RPL), or bubble detectors, and solid-state nuclear track detectors) and active detectors (e.g. tissue equivalent proportional counters and neutron monitors) for dosimetry within water phantoms (Harrison et al., 2017), anthropomorphic phantoms (Miljanić et al., 2014; Majer et al., 2017), and in the vicinity of treatment facilities (Farah et al., 2015; Mojżeszek et al., 2017). The involvement of several European laboratories and reference facilities in the work of Working Group 9 has promoted harmonisation by enabling comparisons to be made between various dosimeters and dosimetric techniques. A continuing objective is to assess the potential use of new and emerging techniques and materials in radiotherapy (e.g. optical fibre and gel dosimeters).

Recent work in out-of-field dosimetry is directed towards assessment of the risk of second cancer induction and other late effects due to the unwanted irradiation of tissues and organs outside the target volume (Miljanić et al., 2014; Majer et al., 2017). The emphasis is on paediatric radiotherapy, where patients may have life expectancies which are sufficiently long that late effects may be expressed. Out-of-field measurements may also be used for providing robust dosimetric data for the development and validation of analytical models (e.g. for treatment planning systems) (Schneider et al., 2017), and as input to epidemiological studies (Harrison, 2017) and other long-term studies of radiation effects.

Development of this theme involves working towards generation of the complete dose specification (i.e. the combined dose) from radiotherapy and associated imaging techniques for planning and treatment verification. This work is carried out in collaboration with Working Group 12 (Dosimetry in Medical Imaging).

Working Group 9 is also studying dosimetric techniques for small radiation fields used in many modern radiotherapy techniques, such as intensity-modulated radiotherapy, CyberKnife, TomoTherapy, Gamma Knife, and proton pencil beam scanning, where the detector dimensions may be comparable to the field size, and full lateral electronic equilibrium may not exist. Similar problems of finite detector size arise near the edges of treatment fields (in regions of high-dose gradient) where most second cancers arise, and for dosimetry within small organ substructures.

Proton therapy poses several particular dosimetric problems, including mixed field (proton, neutron, secondary charged particle, gamma) dosimetry within the patient for combinations of treatment parameters including range and modulation. Several experimental studies of neutron spectrometry using Bonner spheres have been performed in conjunction with dosimetry in the vicinity of proton therapy facilities (Farah et al., 2015, 2017; Mares et al., 2016; Mojżeszek et al., 2017) and within anthropomorphic phantoms used to simulate proton treatments. With the rapidly increasing number of European proton therapy facilities in clinical use, harmonisation of dosimetric techniques is important, and the development of a prototype mailed dosimetry audit system is underway.

Extensive MC transport calculations using MCNP, FLUKA, and GEANT codes provide valuable computational studies of dosimetry in phantoms and ambient mixed radiation fields to complement the experimental programmes.

2.5. Retrospective dosimetry

Working Group 10 (Retrospective Dosimetry) develops and harmonises techniques and methods in biological and physical retrospective dosimetry through a network of contacts, scientific exchange, and scientific collaborations between European laboratories active in this area. The activities of Working Group 10 have also attracted attention outside of Europe, leading to laboratories from the USA and South Korea joining in recent years.

One of the main activities of Working Group 10 is the validation of newly developed physical and biological dosimetry methods through interlaboratory comparisons (ILCs). Such methods have developed rapidly in the past decade, most notably in physical retrospective dosimetry, but often only in a single or in a few laboratories. ILCs within EURADOS currently guarantee the highest level of standardisation achievable. Three ILCs have been performed to date, validating measurement protocols on surface-mount resistors (measurable with OSL), display glass (measurable with TL), and touchscreen glass (measurable with electron paramagnetic resonance (EPR)) of mobile phones as fortuitous dosimeters. The exercises have been realised either using laboratory irradiations (Bassinet et al., 2014; Fattibene et al., 2014; Ainsbury et al., 2017), or in a field test involving a radioactive source placed in the luggage compartment of a bus and phantoms equipped with mobile phones placed in the bus (Woda et al., in prep.). The latter test was also the first ILC where physical retrospective and biological dosimetry (the latter using blood sample tubes placed in Thermos flasks) were performed at the same time and in the same experimental set-up. This is linked to another aim of Working Group 10, namely to establish a multi-parameter approach to dose assessment in retrospective dosimetry.

Methods for estimating the uncertainty of a measured dose are comparatively standardised in biological dosimetry, but are still in an early developmental stage in physical retrospective dosimetry. The status quo of uncertainty estimation across all techniques used in Working Group 10 participating laboratories has been assessed recently (Ainsbury et al., 2018), and was the topic of a training course (with funding from the European Union project CONCERT) provided by Institut de Radioprotection et de Sûreté Nucléaire in June 2017. The final goal of Working Group 10 is to establish a common approach for biological and physical methods, which could make use of advanced techniques such as MC simulations and Bayesian statistics. Software for this purpose is currently being developed.

In 2015, it was decided that a joint EURADOS/International Commission on Radiation Units and Measurements (ICRU) report on retrospective assessment of individual doses for acute exposures to ionising radiation (working title) should be realised. Four members of the report committee are from Working Group 10. The report is expected to be completed by the end of 2018.

A major issue in biological dosimetry is the evaluation of doses following internal or mixed internal and external exposure. On this topic, Working Group 10 has undertaken a major literature review in collaboration with Working Group 7, with expected publication in 2018.

To relate the dose in the material used in physical retrospective dosimetry (e.g. in personal objects) to quantities appropriate for triage in a mass casualty scenario (e.g. 'whole-body' dose/absorbed dose in organ/air kerma), Working Group 10 is collaborating with Working Group 6, focusing on development of conversion algorithms, generating conversion data with uncertainties, and defining the useful dose quantity for emergency scenarios.

2.6. Dosimetry in high-energy radiation fields

The objective of Working Group 11 (Dosimetry in High-energy Radiation Fields) is to increase the expertise regarding field characterisation and dose assessment in situations where high-energy radiation and pulsed fields are found, such as in medicine, research, civil aviation, and space.

The main achievements and current actions of Working Group 11 include comparison of various computer codes assessing galactic cosmic radiation exposure. This initiative has shown that the codes used for occupational dosimetry of aircraft crew provide route dose estimates that are in good agreement and compatible with radiation protection requirements (Beck et al., 2009; Bottollier-Depois et al., 2009). Regarding dose assessment during solar particle events (SPEs), a benchmark has highlighted that the models developed to date require improvement (Beck et al., 2008; Bütikofer and Flückiger, 2013). As such events are rare, one of the difficulties in validating these models is that experimental data coming from measurements on board aircraft are not yet available. Therefore, Working Group 11 set up a network to perform continuous measurement of cosmic radiation at ground level and on board aircrafts in order to produce experimental data, particularly in the case of an SPE. The instrumentation includes simple dosimeters on several aircraft, and ground-based neutron monitors and Bonner sphere neutron spectrometers. A specific protocol has been defined to characterise and calibrate these dosimeters on dedicated flights using a tissue equivalent proportional counter as the reference device.

Another focus of Working Group 11 is investigation of instrument response in pulsed and high-energy fields. In the last few years, the first action focused on intercomparison of area survey meters and personal dosimeters in high-energy and pulsed neutron fields (Silari et al., 2009; Caresana et al., 2014; Trompier et al., 2014), while the second action focused on pulsed photon fields of ultrashort duration (in the range of fs). The current action aims to identify a reference facility for instrument intercomparison with short and ultrashort photon bursts.

Finally, a benchmark exercise has been initiated on high-energy codes and models used to characterise high-energy neutron fields (Rühm et al., 2014), and to assess the corresponding dose in various domains of activity, such as medicine, research, aviation, and space.

2.7. Dosimetry in medical imaging

The focus of Working Group 12 (Dosimetry in Medical Imaging) is harmonisation, evaluation and development of dosimetry methods, intercomparisons, literature reviews, and measurement campaigns to assess occupational as well as patient dose. Working Group 12 is divided into two subgroups: SG1 on staff dosimetry and SG2 on patient dosimetry.

The increasing use of ionising radiation in the medical sector, and publication of the new ICRP recommendations for the dose limit to the lens of the eye for workers have affected occupational exposures. Therefore, SG1 initiated tasks to study dosimetry of the lens of the eye for medical workers, as well as the use of active personal dosimeters (APDs) in hospitals. Recent work of SG1 is directed towards: (1) evaluation of exposure of the lens of the eye of medical staff working with fluoroscopy systems, and preparation of basic guidelines on monitoring the lens of the eye (Carinou et al., 2015; Ciraj-Bjelac et al., 2016; Ferrari et al., 2016); (2) investigation of the present situation and preparation of guidelines on the use of algorithms for estimation of effective dose and dose to the lens of the eye when radiation protection tools are used; and (3) organisation of intercomparisons of dosimeters for the lens of the eye between European individual dosimetry services to check their performance in routine work (Clairand et al., 2016). A second topic is focused on the use of APDs in hospitals. As occupational exposure in medicine is a matter of growing concern, APDs are used increasingly in various fields of application of ionising radiation in medicine. The work is directed towards surveying the present situation on the use of APDs in European hospitals following testing of various APDs in different conditions (continuous and pulsed reference fields, realistic fields in hospitals, and staff use in hospitals), and on studying the influence of the lead apron on calibration of dosimeters.

The work of SG2 is dedicated to patient dosimetry for interventional procedures in cardiology and radiology, as well as dosimetry in cone beam computed tomography (CBCT) imaging. As the number and complexity of interventional cardiology (IC) procedures have been growing steadily, it has become crucial to provide patient-specific skin dose estimates during IC procedures (Dabin et al., 2015; Farah et al., 2015). The aim of this research is to foster the harmonisation of a radiation dose structured report, and to validate skin dose calculation software (by acceptance testing and developing quality control protocols) in IC, which will help to develop patient-specific dosimetry and optimise radiation protection. The second topic of SG2 is considering patient dosimetry associated with various CBCT technologies (i.e. dental, flat detector, and on-board imaging systems). The work is focused on reviewing and collecting studies related to CBCT through questionnaires focusing on dosimetric methodologies used to evaluate organ doses in order to understand dosimetric methods that are used in clinical conditions. Together with Working Group 9, SG2 is also working on improving optimisation of imaging practices in radiotherapy, and generation of a complete dose specification from both radiotherapy and imaging techniques.

3. EURADOS WORK PROGRAMME ON HARMONISATION OF INDIVIDUAL MONITORING

EURADOS began work on harmonisation of individual monitoring for external radiation in 1996 (Bartlett et al., 2001). Since then, Working Group 2 has achieved a number of objectives including: carrying out relevant surveys; production of technical recommendations under contract to the European Commission (EC, 2009); and dissemination via training courses, workshops, and learning network events. A most significant aspect of harmonisation work is the organisation of self-sustaining intercomparisons for passive dosimeters (Fantuzzi et al., 2014; Grimbergen et al., 2016), which has provided benefits for many individual monitoring services (IMSs). The main strands of the current work programme are as follows.

3.1. Intercomparisons

The programme of intercomparisons is intended to continue for as long as there is a need. Intercomparisons entail significant work from the organising group, the irradiating laboratories, and administrative support, but they provide great benefits for IMSs. Not only do they function as routine proficiency tests, but because they are carried out by accredited laboratories, they also provide a means of checking on type-test and traceability data. A second intercomparison for neutron personal dosimeters took place in 2017, and the intercomparisons will continue with one for photon whole-body dosimeters in 2018, and one for extremity dosimeters in 2019.

3.2. Training course

Following publication of the 2009 Technical Recommendations (EC, 2009), Working Group 2 organised formal training courses for staff of IMSs. Based on the recommendations, the four courses delivered to date have been well attended and well received. Demand for these courses is continuing, and while the content is necessarily evolving, further courses are planned. The next course will be in 2019.

3.3. Building networks

One consistent thread of feedback from both the intercomparison participants' meetings and the training courses was how useful students found it to network with colleagues from other IMSs. Accordingly, Working Group 2 is now implementing two new networking approaches. The first is through 'Learning Network' events, held during the EURADOS annual meeting, of which a major component is discussion between IMSs. The inaugural learning network event took place in 2017, and again the intention is for these to continue for as long as they are needed. The second new approach is the development of an online discussion forum. This has been launched in 2017, and will provide a simple way for IMSs to maintain contacts and to hold discussions on a range of topics.

3.4. Further dissemination

Another means of disseminating best practice amongst IMSs is via presentations and publications. Members of Working Group 2 have given oral and poster presentations at international conferences, such as individual monitoring and solid-state dosimetry conferences, and publications have included not only papers in peer-reviewed journals but also official EURADOS reports. Finally, as noted above, best practice can be disseminated by means of technical recommendations. Working Group 2 is currently planning to establish tasks that will lead to two 'best-practice' guides: one to assist IMSs and auditors in interpreting the quality management standard ISO 17025 (ISO, 2005) in the context of individual monitoring, and another to assist IMSs in operating high-quality dose-record-keeping systems that meet new data protection standards.

4. EURADOS STRATEGIC RESEARCH AGENDA

Recently, EURADOS has developed a European strategic research agenda (SRA) on dosimetry. Based on a joint effort of the members of all working groups, five visions were formulated that would, once achieved (within approximately 20 years), significantly improve the dose quantification of individuals in various exposure scenarios. These five visions are:

(1) towards updated fundamental dose concepts and quantities;
(2) towards improved radiation risk estimates deduced from epidemiological cohorts;
(3) towards efficient dose assessment in case of radiological emergencies;
(4) towards integrated personalised dosimetry in medical applications; and

(5) towards improved radiation protection of workers and the public.

Each of these visions is subdivided into so-called 'scientific challenges', which are, in turn, detailed by describing required research lines. The SRA was published as a EURADOS report (Rühm et al., 2014), which is freely downloadable at www.eurados.org, while an extended summary was published by Rühm et al. (2016). Similar SRAs were also developed by the other European research platforms MELODI (Repussard et al., 2018), ALLIANCE (Vandenhove et al., 2018), NERIS (Schneider et al., 2018), and EURAMED (Hoeschen et al., 2018).

A EURADOS workshop was held in 2016 in Neuherberg, Germany, where 23 international organisations interested in the dosimetry of ionising radiation commented on the EURADOS SRA. A summary of this workshop was published recently (Rühm et al., 2017), and a EURADOS task group is currently evaluating the results of this workshop.

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