INTERNATIONAL CONFERENCE ON OCCUPATIONAL RADIATION PROTECTION

STRENGTHENING RADIATION PROTECTION OF WORKERS –

TWENTY YEARS OF PROGRESS AND THE WAY FORWARD

5 – 9 September 2022
Geneva, Switzerland
(CN-300)

Summary Report

International Atomic Energy Agency

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FOREWORD

The Third International Conference on Occupational Radiation Protection was held from 5 to 9 September 2022 in Geneva, Switzerland. The main objective of the conference was to review the global status of occupational radiation protection and to enhance the protection of workers and identify priority actions and future needs to enhance the radiation protection of workers.

The conference was organized by the IAEA, hosted by the Swiss Government, co-sponsored by the International Labour Organization (ILO) and in cooperation with other 16 international organizations / associations. Over 700 participants, among them 280 in-person, exchanged information, shared insights and discussed challenges, representing 105 Member States and 17 international organizations.

The participants at the conference included the representatives of regulatory bodies, workers and their representatives, employers, and other stakeholders involved in the use of radiation sources and in the operation of installations containing or handling radioactive materials including NORM. Other participants were radiation protection experts, researchers, personnel from providers of occupational radiation protection technical services, and manufacturers of radiation emitting apparatus and other radiation sources. The representatives of workers' and employers' organizations, emergency workers/emergency response organisations also were part of the conference participants.

This summary highlights a total of twelve topical sessions that were covered from selected areas of occupational radiation protection during the conference. The topic of each session was introduced by a chairperson, followed by invited presentations and a summary of the session-related contributed papers presented by a Rapporteur. Each topical session was concluded with a plenary discussion. Five of the topical session also included round table discussions, in addition to the young professionals round table. The topical sessions included:

— Review of standards and recommendations: progress over the past twenty years and existing challenges,
— Monitoring and dose assessment of occupational radiation exposures,
— Radiation effects, health risks and worker's health surveillance
— Occupational exposure levels and dose registries,
— Occupational radiation protection in nuclear power plants and nuclear fuel cycle facilities,
— Occupational radiation protection in the workplaces involving exposure to naturally occurring radioactive material, radon, and cosmic rays,
— Occupational radiation protection in medicine,
— Optimization in occupational radiation protection,
— Technical service providers in occupational radiation protection,

- Education and training in occupational radiation protection,
- Safety culture in occupational radiation protection.

In addition, this conference summary refreshed memories of interested parties and people about conference topical presentations, findings, conclusion and recommendations and facilitate the global efforts in improving occupational radiation protection system. Further information can be obtained from conference website at: https://www.iaea.org/events/occupational-radiation-protection-2022

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1 BACKGROUND TO THE CONFERENCE

1.1 Objectives

The Third International Conference on Occupational Radiation Protection was held to review the global status of occupational radiation protection and to enhance the protection of workers. At this conference, radiation protection experts and practitioners from around the world and international organizations shared information and experiences on the implementation of international basic safety standards on radiation protection and safety of radiation sources since the last conference, which was in 2014. In addition, technical and regulatory advances in radiation protection of workers worldwide were discussed. Emerging challenges and opportunities for occupational exposure control to naturally occurring radioactive material and nuclear reactors, as well as the impact of changes in new operational quantities for external radiation exposure were among the important topics that received special attention in presentations and discussions.

1.2 International aspects

1.2.1 International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation, was held in Geneva, Switzerland, from 26 to 30 August 2002.

The Geneva Conference was the first international conference to cover the entire legislative and operational aspects of occupational radiation protection. Some specific recommendations emerged from the conference, noting that occupational radiation protection in general is a success story for the international radiation protection community. There has been a steady upward trend in many key performance indicators, but the picture was not as clear and encouraging for medical and industrial exposures and exposures to natural sources of radiation, particularly mining of ores other than uranium and processing of rare earths. This was considered important because these are the main types of exposure occurring worldwide.

The recommendations and conclusions of the Geneva Conference resulted in an international action plan for occupational radiation protection with fourteen actions identified by the Conference as of particular concern. The action plan was intended to accelerate and guide international efforts to improve occupational radiation protection worldwide. The action plan addressed issues such as strengthening relevant international conventions, developing and maintaining effective safety infrastructures, promoting a safety culture among managements and workers, and harmonizing international radiation protection requirements that are compatible with other occupational health and safety at workplace. The development of education and training and the promotion of information exchange were important components of the action plan, which proposed joint international efforts to support decision making regarding the attribution of health effects to occupational radiation exposure. The protection of specific groups, including pregnant workers to restrict exposure of the embryo or fetus or the breastfed infant, was also addressed.

Although the Geneva Conference made a comprehensive international contribution to the status of occupational radiation protection at that time, much remained to be done, and there were challenges in the areas of medicine, NORM, and the nuclear industry in general. In addition, new developments at the time brought additional challenges that were addressed by the international community at the Second International Conference on Occupational Radiation Protection.

1.2.2 International Conference on Occupational Radiation Protection: Enhancing the Protection of Workers- Gaps, Challenges and Developments held at IAEA's Headquarters in Vienna, Austria, from 1 to 5 December 2014

The Second International Conference on occupational radiation protection was dedicated to enhancing radiation protection of workers worldwide. The conference was organized by the International Atomic Energy Agency (IAEA) and co-sponsored by the International Labour Organization (ILO) in cooperation with 15 organizations. These included the European Commission (EC)), the International Commission on Radiological Protection (ICRP), the International Commission on Radiation Units and Measurements (ICRU), , the International Committee on Non-Destructive Testing (ICNDT), the International Mining and Materials Association (IMMa), the International Organization of Employers (IOE), the International Radiation Protection Association (IRPA), the International Organization for Standardization (ISO), the International Society of Radiology (ISR), the International Society of Radiographers and Radiological Technologists (ISRRT),the International Trade Union Confederation (ITUC), the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the World Health Organization (WHO).

The Vienna Conference was structured to solicit the views of stakeholders - i.e., regulators, employers, workers, radiation protection professionals and international organizations - on occupational radiation protection issues. The conference was attended by more than 471 delegates from 79 member states and 21 international organizations. The Vienna Conference noted that occupational radiation protection has been successful throughout the international community since 2002, as evidenced by many key performance indicators. Although the conference provided a comprehensive international contribution to the state of occupational radiation protection at this time, much remained to be done, and specific challenges were identified in nine key areas, including implementing existing safety standards, strengthening support for countries with less-developed occupational radiation protection programs, improving the safety culture among exposed workers, and convening an international forum for information exchange. In addition, new developments at the time brought additional challenges that needed to be addressed by the international community.

After weeklong discussions, nine key areas of focus were identified, requiring global attention. The Occupational Radiation Protection Call-for-Action was the major outcome from this conference and comprises the following nine key areas.

(a) Implement the existing international safety standards to improve occupational protection of workers

(b) Develop and implement new international guidance
(c) Strengthen assistance to Member States with less developed programs for occupational radiation protection
(d) Promote exchange of operating experience
(e) Increase training and education in occupational radiation protection
(f) Improve safety culture among workers exposed to ionizing radiation
(g) Develop young professionals in the area of radiation protection
(h) Convene an appropriate international forum to exchange additional information
(i) Apply the graded approach of the IAEA International Basic Safety Standards (BSS): Radiation Protection and the Safety of Radiation Sources in protecting workers against exposures to elevated levels of naturally occurring radiation or radioactive materials

The overall objective of the Call-for-Action was to combine the efforts of relevant international organizations, particularly the IAEA and ILO, to assist their Member States in establishing, maintaining, and, if necessary, improving programs for the radiation protection of workers. Implementation of the proposed actions would enhance international efforts in nine high-priority areas (listed in the action plan) identified by the Vienna Conference as being of particular concern. The Call-for-Action addresses important aspects of the control of occupational exposures, which, as noted at the Vienna Conference, have an international dimension. Therefore, the plan addresses the implementation of existing international standards and the development of new guidelines, increased support for Member States with less developed occupational radiation protection programs, and the promotion of the exchange of operating experience. Improving education and training in occupational radiation protection, promoting a safety culture at the management level and among workers, and encouraging young professionals in radiation protection are also part of the plan. In addition, the plan calls for the convening of appropriate international forums for the exchange of experience and improved application of graded approach to international basic safety standards. Continued promotion of safety culture will support consistent application and improve understanding and communication of safety standards.

There was a growing awareness of the need to protect workers in industries involving NORM and to apply a graded approach to managing worker protection through regulatory agencies and operator resources. An exchange of experience is needed to establish regulatory requirements for radiation protection in industrial processes involving NORM. Regulation and management of radon exposure in the workplace was also an important issue.

Occupational exposure in industrial and research facilities are generally quite acceptable, despite occasional accidents with significant exposure consequences. Optimization is a key issue for radiation protection in the workplace in nuclear industry, industrial radiography, and interventional cardiology. Information systems (e.g., ISOE[1], ISEMIR[2]) and networks (e.g., ORPNET[3]) aimed at facilitating the exchange of experience on optimization have been established. It was expected that such approaches will be extended to other sectors, such as industrial processes involving NORM. The results and observations of peer reviews

[1] https://www.isoe-network.net/
[2] https://nucleus.iaea.org/isemir
[3] https://www.iaea.org/services/networks/orpnet

(such as ORPAS[4]) have shown that such reviews have a positive impact on the implementation of optimization in some facilities.

In many member states, nuclear power is being used to meet rapidly increasing energy demands. The introduction of nuclear power plants (NPPs) in the so-called "nuclear embarking countries" and the development of new types of nuclear reactors, such as SMRs, have led to new challenges for radiation protection in the workplace. As many nuclear reactors reach the end of their operating lives, radiation protection during decommissioning operations has greater implications for radiation protection of workers.

The exposure of workers in medical practice, including the use of conventional radiology for diagnosis and therapy, is generally well controlled and meets international safety standards. However, the increasing use of medical procedures involving ionizing radiation and greater access to this health technology have resulted in a rapid increase in the number of occupationally exposed workers in medicine over the years. Certain medical procedures, such as interventional cardiology, can result in significant occupational exposure. It is an ongoing challenge to control exposure and train healthcare professionals on radiation protection issues.

Capacity building of technical services in radiation protection and stakeholder involvement, including regulators and representatives of workers' and employers' organizations, are essential for occupational radiation protection decision making in developing countries. With the publication of the joint ICRU/ICRP report (ICRU Report 95) on operational quantities for external radiation exposure, the implications for existing radiation monitoring techniques need to be reassessed.

2 OPENING OF CONFERENCE

During the opening of the conference, remarks were given by the IAEA, ILO, and all Co-sponsoring organizations. The remarks were followed by Conference President 's outline on six current challenges in occupational radiation protection. The first challenge is the expected increase in occupational exposures due to the increase in medical procedures resulting from improved access to health technologies. This presents an ongoing challenge for limiting exposure control and training of health care professionals in radiation protection issues. Second, there is growing awareness and attention to the need for worker protection in industries that work with NORM, and to the need for a graded approach to managing worker protection by regulatory agencies and operator resources. In this area, the management of radon exposure in the workplace is also an important issue. Third, new challenges for occupational radiation protection arise from the introduction of nuclear power plants in the embarking countries and the design of new types of nuclear reactors such as small modular reactors. The fourth challenge is the increasing need to protect workers performing special decommissioning work at many nuclear reactors that are near to the end of their operating lives. The fifth challenge is the need to reassess the impact of the publication of the joint ICRU/ICRP report on new operational quantities for external radiation exposure on existing radiation monitoring techniques. The sixth challenge is the need to gain experience with the revised data set recently provided by the

[4] https://www.iaea.org/services/review-missions/occupational-radiation-protection-appraisal-service-orpas

ICRP for the assessment of internal occupational exposure to radionuclides. All these new developments should be linked to the ongoing process of revising the radiation protection system established by ICRP. The President also noted other existing tasks, such as the importance of gathering experience and feedback from the implementation of the international basic safety standards for harmonization and future revision of the standards. In particular, the lowering of the dose limit for the lens of the eye, which is a practical implementation and compliance challenge, would be discussed. A high-level safety culture is necessary and should be promoted to prevent incidents or accidents. The goal of the conference, was to focus efforts in these areas and maximize the associated positive impact for future international work, taking into account the problems, current trends and developments. The objectives of the conference were summarized as:

(a) To exchange information and experience in the field of occupational radiation protection,
(b) To review technical and regulatory advances, challenges, and opportunities since the last conference on the topic organized in 2014,
(c) To review the global situation on radiation protection of workers,
(d) To identify priority actions and future needs,
(e) To formulate conclusions and recommendations.

A keynote lecture was given on "Protection of Workers against Occupational Exposures to ionizing radiation: Genesis, Evolution, Achievements, Challenges." The intergovernmental regime for occupational radiation protection, which led to an international occupational radiation protection program, was explained as one of the achievements behind current international safety standards. The need to link the intergovernmental regime with the new scientific consensus and current challenges was emphasized. The first challenge cited for the occupational radiation protection program was the imprecise meaning of the term "occupational exposure." Should exposure of aircrew or "sanitas per aquam" (SPA), which translates as “health through water,” be covered by the ILO Convention or not. The second challenge was whether workers’ proven chances of incurring radiation health effects be equated to conjectures of potential effects. The legal imputation of occupational harm and quantities and units for controlling workers were also identified as challenges. The last challenge was on a new paradigm for protecting workers involved in electricity generation. The source with the highest radiation exposure to workers is coal, not nuclear. Finding a logical paradigm for occupational health and safety for natural radiation was mentioned as another major challenge for the future. To address these challenges, the presenter suggested that the IAEA and ILO, in cooperation with workers and employers, consider some means to address these issues.

3 REVIEW OF STANDARDS AND RECOMMENDATIONS: PROGRESS OVER THE PAST TWENTY YEARS AND EXISTING CHALLENGES

The IAEA estimated the number of monitored workers at over 24 million over the past two decades. This figure includes 12.6 million exposed to natural sources of radiation and about 11.4 million exposed to artificial sources. Among artificial sources, the number of workers in the nuclear industry is estimated at 860,000 and in other industries at 870,000. A review analysis shows that occupational exposure control, dose assessment, monitoring, and recordkeeping requirements have remained stable over the past two decades. As one of the actions under the Occupational Radiation Protection Call-for-Action (2014 Vienna Call-for-Action), the radiation protection community has continued to implement existing international safety standards to improve the protection of workers in the workplace, including assisting Member States in facilitating implementation and promoting a holistic approach to worker protection. In addition, the following achievements were highlighted. The IAEA and the relevant organizations completed the implementation of all nine Actions of the Action Plan on Occupational Radiation Protection eight years ago. The Agency continued to develop and implement new international safety guides for occupational radiation protection in different exposure situations, including advanced accelerator facilities and interventional radiology. These documents include the General Safety Guide, Occupational Radiation Protection, IAEA Safety Standards Series No. GSG-7, which was jointly developed by the IAEA and ILO and published in 2018. The publication of GSG-7, which is also one of the nine actions of the 2014 Vienna Call-for-Action, provides guidance on meeting the occupational exposure requirements of GSR Part 3.

The conference was informed that the mission regarding the 2014 Vienna Call-for-Action has largely been accomplished. Other published documents include Safety Guide for the Protection of Workers Against Exposure Due to Radon, No. SSG-32 (2005), Specific Safety Guide for the Application of the Concept of Exemption, No. RS -G-1.7 (2004), and Radiation Protection and Management of NORM Residues in the Phosphate Industry, SRS No. 78 (2013). Other success stories include the implementation of the IAEA-occupational radiation protection in the workplace and continued support to member states for training, review missions, or advisory services. The introduction of e-learning in occupational radiation protection as part of the IAEA's learning management system are also among the successes. Another achievement is the strengthening of the operation of ORPNET, ISEMIR and ORPAS services to Member States. The new General Safety Guide for Situations of Existing Exposures (EES) is being prepared as an overarching guidance document on this subject. Other documents in preparation include the Safety Guide on the Application of the Concept of Exemption (DS499) and the Safety Guide on the Application of the Concept of Clearance (DS500). A Safety Report or TECDOC on international trade is still under consideration.

The ICRP discussed recent developments and challenges for the future of occupational radiation protection. Participants were reminded of two important developments in ICRP Recommendations 103, namely the three types of exposure situations (planned, existing, and emergency) and the need to consider the views and concerns of stakeholders when optimizing protection. Conference participants were informed that since 2014, the ICRP has continued to provide recommendations for the radiation protection community in various publications, including the ethical values adopted in ICRP Publication 138. The ICRP supports the need for an integrated and graded approach to address the management of existing exposure situations, given the potentially high cost of regulation compared to exposure reduction. A similar approach has been recommended for radiation protection in industrial processes involving NORM, through characterization of the situation and subsequent establishment of reference levels (with the exception of radon). Ongoing work addresses, among other things, reasonableness and tolerability in the radiation protection system and risk and dose assessment for radiological protection of astronauts.

The EC reviewed occupational radiation protection in the workplace with respect to framework and requirements in Europe. The Treaty establishing the European Atomic Energy Community (Euratom Treaty) – 1957, the Treaty of Lisbon (Treaty on European Union and the Treaty on the Functioning of the European Union) - 2009 were mentioned as the legal basis for framework and arrangements. The Euratom Treaty established the European Atomic Energy Community, which laid down European basic standards for the protection of the health of the public, workers, and patients against the harmful effects of ionizing radiation and ensured their application. The BSS directive (2014) are legally binding requirements for EU member states, which have been transposed into national regulations. Among the requirements of the BSS Directive is the protection of workers, members of the public, and patients. The European Basic Standards Directive provide a similar level of protection to the International Basic Safety Standards (GSR Part 3). With respect to radon in the workplace, the employer is assigned a clear responsibility to protect workers. Radon measurements at the workplace are part of the requirements and should be based on a graded approach. It is required to keep under review exposures ≤ 6mSv/a, while exposures > 6mSv/a are managed as a planned exposure situation. Other requirements relate to the protection of aircrew and space workers from cosmic radiation and the protection of workers during radiological or nuclear emergencies. EC pointed out that the Member States of the European Union have to transpose the requirements of the Basic Standards Directive into national legislations by February 2018 and that the transposition into practice is still ongoing. EC maintains international cooperation with the heads of the European Radiological Protection Competent Authorities (HERCA), ICRP, IAEA, WHO, OECD/NEA, IRPA, UNSCEAR, Norway, Switzerland and the United Kingdom.

US-NRC discussed the implementation of national radiation safety requirements like IAEA safety standards. US-NRC was established by the Code of Federal Regulations (CFR), which describes safety regulations and requirements for the radiation protection system. The NRC regulates by developing regulations and guidance for applicants and licensees, licenses or certifies applicants to use nuclear materials, operate nuclear facilities, and decommissioning facilities. NRC's other responsibilities include inspecting and evaluating licensee operations and facilities to ensure that licensees comply with NRC requirements, responding to incidents, investigating alleged violations, and taking appropriate follow-up or enforcement actions when necessary. Several guidance documents are available, including an occupational health guide that addresses effective dose equivalent measurement methods, personnel monitoring devices, bioassay programs, and ALARA programs. Other guides address respiratory protection, surveys/air sampling, radiation safety training, planned special exposures and very high radiation control areas. Current NRC work in the area of occupational radiation protection includes the development of regulations to protect workers from cosmic radiation in the aviation industry (aircrew and space personnel). Regarding international cooperation, US-NRC works with several national and international organizations, including the IAEA, and has supported the development of IAEA safety guides, including Occupational Radiation

Protection (GSG-7), Radiation Safety in the Medical Use of Ionizing Radiation (SSG-46), and Radiation Protection of the Public and the Environment (GSG-8).

In summary, the regulatory framework is important to improve occupational exposure control through enforcement, including updated regulations, guidance documents, and licensing requirements. Radiation safety training is also important to improve safety culture. National qualifications recognition criteria for radiation protection officers are always needed for better implementation of safety requirements.

4 MONITORING AND DOSE ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURES

The ICRU presented a keynote paper on ICRU Report 95: Operational Quantities for External Radiation Exposure and discussed what changes can be expected for radiation protection related units and quantities. Current operational quantities are defined as the product of physical quantities and appropriate conversion coefficients derived from geometric phantoms. The ICRU 95 paradigm shift defines operational quantities as the product of a field quantity (in this case, fluence) and a conversion coefficient derived from anthropomorphic phantoms. Features of the new operational quantities include a better approximation of effective dose, definition of quantities to limit tissue effects (local dose to skin and eye lens) as absorbed dose, and applicability to more types of radiation, e.g., positrons, protons, and pions. Other features include a much wider energy range, quantities for photons calculated with full electron transport and in kerma approximation (for calibration). The results of the studies performed to investigate the impact of the new operational quantities led to the following conclusions: Dosimeter response – almost unchanged for area dosimeters with cut-off E > 50 keV, which means recalibration of sensitivity (15%). Whole body dosimeters with low photon energies require redesign of filters or algorithms for multidetector types. Neutron monitors continue to provide “good estimates” but recalibration is required to adjust IEC acceptance limits. No changes are required for extremity dosimeters. Almost unchanged for eye lens dosimeters, but minor recalibration may be required.

The influence of the change on the dose registries shows that they should record the effective dose E, that the new quantities provide a better approximation of E, and that there will be no difference for most workers for whom the monthly dose is (almost) zero. Other influences are the measurement uncertainty at low doses (trumpet curve) that must be achieved, the recorded value for workers with significant dose that should be somewhat lower, and the need to study more details for the case of medical staff in interventional radiology. The use of realistic human phantoms allows a more accurate assessment of occupational radiation dose in accordance with ICRU Report 95, which allows operational quantities to be defined in the same way as the protection quantities using the same phantoms and weighting factors. System of quantities is easier to understand because the numerical values and their trends with energy are consistent with the protection quantities. The changing dose values in real radiation fields do not justify changes in radiation protection practices. Additional studies are needed for radiation fields in different professions.

The European Radiation Dosimetry Group (EURADOS) discussed “External dosimetry: status of the art and technologies” The presenter cautioned against the notion that monitoring workers for external dosimetry is easy, although there are a lot of problems. Several considerations were discussed that are necessary for a dosimeter to measure dose as intended. These include the choice of a detector appropriate for the dose being measured, the need to understand the characteristics of type testing, metrological traceability in accredited calibration laboratories, estimation of uncertainties, application of appropriate procedures, and the need for services to be accredited. Future improvements in current technologies, such as the use of artificial intelligence to analyze neutron dosimeters based on fluorescent solid-state nuclear track detectors, are expected. Other anticipated improvements in new technologies include hybrid dosimeters, which are legal dosimeters and do not need to be returned to individual monitoring services, since the dose can be read via a mobile device or PC as needed. In this context, the IEC 61526 document for performance testing is being revised to address these potential new technologies. Online personal dosimetry using computational methods (PODIUM) is another new technology being investigated as part of the PODIUM project (2018-2019). The results of feasibility studies on two situations at neutron workstations and in interventional radiology were presented as part of a paradigm shift. Computational dosimetry is expected to overcome the problems of the current individual monitoring system based on physical dosemeters.

The ICRP's work on internal dosimetry was presented, citing the current formalism for calculating the committed effective dose. This involves measuring the ingested radioactivity and then calculating the committed effective dose using dose conversion coefficients. The calculation of dose after intake is a complex procedure that takes into account energy and dose for each isotope and chemical form (and for each particle size). Therefore, the procedure is limited to experts, and the ICRP proposes tools that allow non-experts to perform rapid dose estimation. The tool considers biokinetic models, dose coefficients, and bioassay functions. The biokinetic models describe where each radionuclide is deposited and how long it remains there. There is a general biokinetic model, models that describe uptake, and models that describe systemic behavior and whose parameters are element (or family) specific. The data needed to calculate the committed effective dose are provided by the ICRP, and these are nuclear decay data for dosimetry calculation, computational phantoms for reference individuals, and radiation and tissue weighting factors. The ICRP proposes tools that allow non-experts to make rapid dose estimates using only dose coefficients and bioassay functions. In this simplified method, dose is determined as the product of intake and the committed effective dose coefficient (CEDC). The most recent updates to the existing models for workers (new occupational intake of Radionuclides (OIR) series, 5 volumes from 2015 to 2022) are included in ICRP Publications 130, 134, 137, 141, and 151. Revision of all biokinetic models using new phantoms and new weighting factors was completed. Coefficients and bioassay functions for about 1200 isotopes, inhalation, ingestion, and injection of various chemical forms and particle sizes from 0.001 µm to 20 µm are available through the free downloadable ICRP/OIR app data viewer.

The Paul Scherrer Institute of Switzerland provided an overview of advances in solid-state dosimetry (SSD) and its potential use in individual monitoring. The historical development of the various detectors since 1925 was described. The relevance of SSD is demonstrated by its high sensitivity, small size, passiveness, reusability, low cost, and widespread use. An overview of the theoretical basis of the various SSD technologies was given. These include thermal luminescence (TL), optically stimulated luminescence, radio-photoluminescence (RPL), and the recently introduced fluorescent nuclear track detectors (FNTD). In addition, recent technological developments, i.e., self-readable dosimeters and direct ion storage (DIS) as potential dosimeters, were presented. Solid-state dosimetry remains important for individual monitoring, and some new technologies are being introduced and may reduce the need for passive dosimeters.

In summary, the use of realistic human phantoms provides for more accurate occupational radiation dose assessment by the ICRU report 95. This enables to define operational quantities in the same way as the protection quantities, using same phantoms and weighting factors. There will be some changes in practice, and it will be a challenge to redesign the characterization of personal dosimeters, especially for gamma radiation dosemeter at low energies. Solid-state dosimetry is still important for individual monitoring, but new technologies are emerging that will reduce the need for passive dosimeters in the future. Regarding internal dosimetry, the ICRP is working to provide conversion coefficients to simplify the current complicated methodology. Eye lens dosimetry with online dosimetry simulation and application for new techniques is also among the new innovations.

5 RADIATION EFFECTS, HEALTH RISKS AND WORKER’S HEALTH SURVEILLANCE

UNSCEAR presented the report “Attributing health effects to ionizing radiation and inferring risks -UNSCEAR 2012 Report, Annex A”," which updates the state of knowledge on health risks associated with occupational exposure to ionizing radiation. The motivation for this report was to identify an increase in cancer rates due to the nature and extent of the consequences of the Chernobyl accident. The information would be useful in clarifying the assessment of potential harm from ionizing radiation and attributability of the health effects of exposure. There is a difference between actual observations of health effects in an individual or population (past or present) and the risk of health effects in an individual or population (future). Actual observations can be obtained from clinical studies of actual cases, epidemiological studies of changes in the frequency of occurrence of health effects in exposed populations, scientific method to test causal hypotheses, and attribute observed outcomes to a cause by excluding other possible causes. On the other hand, the risk of health effects (in the future) is based on scientific inference of risk, frequentist inference (limit of relative frequency of many observations), and Bayesian inference (gaps in observations are filled by expert judgment). Another basis is risk assessment, in which predictions are made when an increased frequency of effects is considered proven based on assumptions.

It is also important to distinguish between probability of causation and attribution. The probability of causation is an inference for an individual based on observations of populations that requires an assumption about the model of dose response. Attribution is not based on the dose-response model, but on the exclusion of other possible causes. Probability of causation is estimated from population studies, but to date there is no biomarker that identifies which cancers are caused by ionizing radiation. Current estimates indicate that a population exposure (with a baseline incidence of 20% cancer-related deaths) of 1 Gy would increase the incidence of cancer-related deaths by 10%. Problems noted with population studies include overcoming statistical fluctuations (uncertainty increases with decreasing dose) and eliminating bias and confounding. Another problem may be that, surprisingly, there is no statistically significant increase in the frequency of radiation cancer deaths in adults only from 100 mGy upwards (low LET radiation). Attribution of an observed health effect in an individual to radiation exposure can be made for deterministic and stochastic effects. An observed deterministic effect in an individual can be clearly attributed to radiation exposure if other possible alternative causes are excluded. An observed stochastic effect in an individual cannot be unambiguously attributed to radiation exposure because radiation exposure is not the only possible cause and there are currently no biomarkers specific to radiation exposure. Therefore, the observed increased frequency of stochastic effects in a population cannot be reliably attributed to chronic radiation exposure at typical average global background levels because of uncertainties associated with assessment of risks at low doses, the current lack of radiation-specific biomarkers for health effects, and the insufficient statistical power of epidemiological studies. Similarly, an observed increase in the incidence of hereditary diseases in the human population cannot currently be attributed to radiation exposure, although this has been demonstrated in animal studies. Regarding low-dose risk assessment, UNSCEAR does not recommend multiplying very low doses by large numbers of individuals to estimate the number of radiation-induced health effects within a population exposed to incremental doses at levels equal to or below natural background levels. Public health agencies need to allocate resources appropriately, and this may require making projections of the number of health effects for comparative purposes. The presentation concluded that the method presented, although based on reasonable but untestable assumptions, could be useful for such purposes, provided it is applied consistently, uncertainties in the assessments are fully accounted for, and no inferences are made about population health.

The ICRP outlined what has been learned from epidemiological studies of workers into eight categories of studies. Radiation-exposed populations are studied to Japanese atomic bomb survivors were exposed to acute radiation, mainly gamma radiation, followed by a life span study (LSS), which is central to estimating radiation risk. Epidemiologic studies use medically exposed groups selected for disease status, so caution is needed in interpretation. Environmentally exposed groups are also a possible route to studies, although determining exposure levels is often problematic. Epidemiologic studies are conducted in occupationally exposed groups, which provides the opportunity to study protracted exposure at low levels, often with prospective measurements of individual doses. Studies have examined inhalation of radon-222 and its radioactive progeny in underground miners, such as uranium and iron miners. The study also addresses radium-based luminous dial painters, mainly young women, who accidentally ingest large amounts of radium. The studies also address radiologists/radiographers/medical professionals where early workers accumulated moderate/high doses of x-rays, and the seventh category is aircrew exposed to cosmic rays, including neutrons. Another study route is to nuclear industry workers from North America/United Kingdom/France/Rest of the World, formerly USSR (Mayak, Chernobyl “liquidators”). In summary, studies of occupationally exposed cohorts show broad agreement with the risk dose responses of survivors of the Hiroshima and Nagasaki atomic bombs. Studies of miners show a radon-related lung cancer risk consistent with a relative biological effectiveness of α-particles of 20. Studies of nuclear workers are beginning to provide meaningful direct estimates of cancer risk at low photon exposures, since the risk at a range of low doses is comparable to that of acutely exposed Japanese atomic bomb survivors. Uncertainties, such as those associated with doses received during early nuclear operations, must be considered, which is important when relating protracted to acute exposures. Plutonium workers have a plutonium-related lung cancer compatible with an α-particle relative biological effectiveness of 20. The current results are largely reassuring with respect to the implications for radiological protection.

The ILO discussed a health surveillance program for workers exposed to occupational ionizing radiation and a compensation program. The ILO addresses occupational health issues that include biological risks, chemical risks, physical risks, ergonomic factors, and psychosocial factors. The problems can lead to occupational diseases or injuries or both. For example, occupational health and safety in mining can lead to occupational diseases from diesel fumes, vibration, noise (from dust), or UV exposure (from radon). Examples of risk factors that can lead to injuries include vehicles, biological agents, mechanical accidents, electricity, floods, and fire. Ergonomics, microclimate gases (methane, ammonia) can cause occupational diseases as well as injuries. As for ionizing radiation, it is known that it can cause health damage. The details of the following important health surveillance instruments for workers occupationally exposed to ionizing radiation such ILO Conventions: No. 115 (on radiation protection of workers) and No. 161 (on occupational health services), and ILO Code of Practice on radiation protection of workers, were provided. Other tools include the Basic Safety Standards (BSS), the ILO Technical and Ethical Guidelines on Workers' Health Surveillance, and the IAEA/ILO/ WHO Safety Report on Health Surveillance of Persons Occupationally Exposed to Ionizing Radiation: Guidance for Occupational Physicians. Some of the points highlighted were the following. The health surveillance requirements of the BSS consist of medical examinations that correspond to the hazards of the workplace, i.e., exposure, noise, dust, chemicals, task-related assessments. This includes assessing conditions that affect the ability to wear and use personal protective equipment (PPE), hear alarms, use specialized tools and equipment, and health status when working with non-sealed sources of radiation, i.e., skin conditions such as eczema, psoriasis, etc. It is important to note that there is no general suitability for employment, as there is no case of absolute "unfitness" for employment. Suitability can only be defined in relation to a specific job or type of work. The purpose of health examinations is to assess the health status of workers according to the principles of sound occupational health service and to prevent and protect against deterioration in the health status of workers and to assess suitability for a particular type of work. It is rare for radiation exposure to significantly affect the fitness of worker to work with radiation. Assessment of psychological fitness for work with radiation and ophthalmologic assessment of the lens of the eye are also part of health surveillance. Medical examinations are intended to protect and promote workers' health as well as to protect access to work, eligibility for compensation, health insurance benefits, and social protection. Medical examinations should therefore not serve as a substitute for preventive and control measures, but rather to improve working conditions in a way that facilitates the adaptation of work to workers. Medical examinations should therefore not be routine but appropriate to occupational risks. For legal and other reasons, medical examinations may also be conducted at or after termination of the worker's employment. Genetic examinations in connection with work constitute a disproportionate interference with the rights of individuals since the current state of scientific knowledge is insufficient to justify their use for occupational health purposes. Importantly, workers have the right to access their personal health and medical records, but any other access should be limited to medical professionals.

The WHO presented on health and safety of health workers exposed to ionizing radiation. Health worker groups at risk for radiation include diagnostic imaging, interventional radiology and therapeutic radiation oncology professionals, trauma facilities, and others (medical physicists, biomedical scientists, clinical and service technicians). Radiation protection principles were reviewed using two exposure situations (planned and emergency). Strategies for preventing radiation exposures in health care settings were then discussed, including training workers in the safe use of equipment and radiation sources, providing personal protective equipment, and developing standard operating procedures for actions to be taken in the event of an accidental radiation exposure. In summary, radiation protection of healthcare workers is essential and should be based on three fundamental principles: justification, optimization of protection, and application of dose limits. The most important radiation protection measures are reducing the time for the workers who are exposed to the radiation source, increasing the distance between the worker and the radiation source, and using appropriate shielding mechanisms. In addition, regular monitoring of radiation exposure is critical to limiting unwanted radiation exposures.

The main conclusion was that integrated health and safety management in an organization can prevent many occupational accidents. The role of international organizations in promoting improved access to occupational, health and safety services, including worker health surveillance, was common to all presentations.

6 OCCUPATIONAL EXPOSURE LEVELS AND DOSE REGISTRIES

The keynote presentation was given by Sweden (on behalf of UNSCEAR) and addressed occupational exposure to ionizing radiation: UNSCEAR Report 2020/2021, Appendix D. UNSCEAR has been evaluating levels of occupational exposure since 1962, and the current report contain an evaluation of exposure for the period 2003-2014. The main objective of the assessments is to determine the average annual effective dose and collective doses to workers in each occupational sectors and subsectors, for both natural and human-made radiation sources. The UNSCEAR evaluation is based on data collection from different sources, of which a survey among member states is the most important one. Fifty-seven countries participated in the recent survey, and 31 in a supplementary IAEA survey in 2020. In addition, a literature review was conducted, covering 692 articles, of which about 50% met UNSCEAR quality criteria. UNSCEAR also collect supporting data from other sources such as the IAEA, OECD/NEA, International Civil Aviation Organization (ICAO), ISOE, World Nuclear Association (WNA), and national reports. In assessing occupational exposure, UNSCEAR faced the following challenges.

- Comparing exposure data between countries (difference in protocols for monitoring and reporting, types of dosimetry technique, formatting responses i.e., different exposure intervals, accounting for not measurably exposed workers, and accounting for transient i.e., temporary workers).
- Incomplete data sets.

Estimates of annual exposure is conducted for 5-year intervals. The estimates for the period 2010-2014 show that approximately 12.6 million workers were exposed to natural sources, including 750,000 in civil aviation, 8,000,000 in coal mining/processing, and 3,800,000 in mineral extraction/processing. This means that about 12 million workers (about 94%) were employed in mining industry. No evaluation of number of workers in gas and oil extraction industry and radon in the workplace were conducted. The estimated annual collective effective dose from natural sources was 2,030 man.Sv in civil aviation, 12,800 man

Sv in coal extraction/processing, and 9,500 man Sv in mineral extraction/processing, for a total of 24,300 man Sv. The respective weighted average annual effective doses were 2.7, 1.6, and 2.5 mSv, giving an annual effective dose of 1.9 mSv for all work groups. During the same period, a total of 11.4 million workers exposed to human-made sources were monitored worldwide, 80% of whom were in the medical field. The total collective dose caused by human-made sources was 5,460 man Sv with a weighted average annual effective dose of 0.5 mSv. The number of monitored workers in the nuclear fuel cycle was 760,000, contributing to an annual collective effective dose of 485 man Sv. In the medical sector the annual collective effective dose of 4,500 man Sv with a weighted average annual effective dose of 0.5 mSv was contributed by 760.00 monitored workers. In industry, the number of monitored workers was 1,100,000 and contributed to an annual collective effective dose of 437 man Sv with a weighted average annual effective dose of 0.4 mSv. For other uses, the number of workers monitored was 540,000 and contributed to an annual collective effective dose of 38 man Sv and a weighted average annual effective dose of 0.1 mSv. Using the data presented, the global average annual effective dose for all workers was estimated to be 1.2 mSv, which is about 2/3 of the estimated value for the 1995-1999 period. In addition, the global average annual effective dose for workers exposed to human-made sources was estimated to 0.5 mSv, while for natural radiation sources it was 2 mSv. One of the implications of UNSCEAR Report 2020/2021 discussed was the importance and need for additional Member States of UNSCEAR to report in the future. It is expected that the participation of Member States will maintain and expand the Committee's network of national contacts and improve the quality, representativeness, and reliability of the Committee's evaluations of ionizing radiation sources and exposure levels. In addition, cooperation with Member States and international organizations has been and continues to be critical. Although monitoring of worker exposure to radon is not mandated in many countries, it is important to continue to collect information on exposure and to record the types of workplaces where radon may be a source of exposure.

Germany presented a report from the National Dose Registry (SSR) on occupational exposure in Germany. The SSR is a central federal institution and is operated by the Federal Office for Radiation Protection (BfS) and was established in 1989. By 2019, the SSR has introduced a personal number in the SSR based on an encrypted social security number. The main tasks of the SSR include centralized recording of occupational radiation doses and the issuance of passbooks, the central surveillance of dose limits and the issuance of radiation passbooks, the provision of information when dose limits are exceeded, and the issuance of encrypted personal numbers. Currently, 420,000 workers from 20,000 companies are monitored, and monthly dose entries amount to 360,000. Overall, the database shows 2,000,000 monitored persons from 120,000 companies and 121,000 dose entries. The statistics also show that in 2021, a total of 418,000 workers were monitored, with the number of measurably exposed individuals in the same year being 99,000. The collective annual dose for all monitored individuals was 26.4 person-Sv for air crew, 0.9 person-Sv for radon and NORM, and 16.3 person-Sv for medical applications. The collective annual dose for nuclear, general industry, research, and emergency respondents was 2.6, 7.3, 0.5, and less than 0.01 person-Sv. respectively. The mean annual effective dose for all measurably exposed persons was less than 4 person-mSv. For cockpit and cabin crew, the mean effective monthly dose from 2013-2021 was less than 0.25 mSv. A decreasing trend regarding valuation of radiation passbooks was observed from 2011 to 2021.

China presented on national dose registry for workers occupationally exposed to ionizing radiation (2009-2021). There are 600,000 occupationally exposed workers, including 420,000 in the medical facilities and activities and about 175,000 in the industrial facilities and activities. There are three major service providers, including uranium mines and NPPs, but the number of commercial service providers is over 300. One challenge is the quality of individual doses, which led to the establishment of a national dosimetry registry. The Chinese National Dose Registry (NDR) has been in operation since 2005. The NDR has both an offline and web-based format and has been in existence for 30 years. Key findings show that more than 97.3% of workers received an average effective dose of less than 1 mSv in 2021. Exposure in interventional radiology and nuclear medicine is higher than levels in other categories. The effective dose has decreased while the collective dose has increased approximately, and the variations in personal doses for workers were statistically significant.

The Centre for Radiation Protection and Hygiene (CPHR), Cuba, reported on the experience of implementing the National Dose Registry (NDR) in Latin America and the Caribbean. At the beginning, the NDR had operational problems, such as the dispersion of information, incomplete information, and different formats and structures. In addition, the data structure of the different dosimetry services was not standardized, which prevented proper integration. In addition, it was not possible to perform efficient statistical analyzes because few data were available to characterize the radiological situation in the country. A "decentralized" information management that was primarily based on the needs of the services and laboratories rather than on the needs of the NDR. Cuba and Brazil have experience in the design, implementation, and operation of national dose registries (NDRs), and an IAEA-supported project has developed a prototype NDR for Latin America. Currently, the NDR has been designed, developed, and validated. There is a functional version of the National Dose Registry in Spanish, where dosimetry information is controlled and accessible according to national regulations. The limited access to the NDR is consistent with the fact that dosimetry information is confidential in most countries and access is therefore restricted. The English version was developed taking into account the experience gained from implementation in Latin America and the Caribbean. Several steps to implement the NDR were described.

Key lessons learned from the implementation of NDR in Latin America and the Caribbean region were highlighted. The NDR may be located at the regulatory body or other entity responsible for processing and preserving historical dosimetry data, Regulatory Authority is responsible for the NDR (regardless of its location) and for the policies developed in the country for the management, retention, and proper operation of the NDR. It is recommended that only the NDR be implemented in the country, even if there are multiple regulators. If the NDR is located at a dosimetry service provider, which is relevant for small countries, it is important to separate the two functions. The situation is different and more complex when there are multiple dosimetry service providers in a country, as there is a need to standardize information at the national level so that all providers can report to the NDR in the same format. A great deal of effort is required when it comes to recovering information generated over the years by different dosimetry service providers. It is recommended that each laboratory providing individual monitoring services develop the necessary interface tool to convert the information from their management systems to the data format established by the NDR. The NDR facilitates a centralized system for storing personal dosimetry data. It is a tool that contributes to the improvement of safety surveillance and maintain the dose assessment system. Its implementation can provide regulators with a tool to verify compliance with dose levels from regional dose registries such as the European Occupational Radiation Exposure Platform (ESOREX).

Ghana discussed the national experience with the Dose Management System (DMS) and NDR in managing occupational radiation exposures in Africa. The DMS, developed by the IAEA to process and record dose assessments obtained using specific dosimetry methods for monitoring external occupational exposure, is in use. The system, which has been in use at the Radiation Protection Institute for more than a decade, allows for the general management and analysis of data from the monitoring of occupationally exposed workers in the medical field, industry and research using thermoluminescence dosimetry. There is a newly acquired DMS on a pilot basis, which consists of an integrated system for user-friendly storage, processing and control of internal and external dosimetry data. The system has modules for data entry, updating, worker registration, maintenance, and personal dose analysis. It also includes a group of classifiers that facilitate the user's work, as well as a module for generating reports and correlating results. The NDR software, in turn, is based on the Chinese Radiation Workers Registry provided by the National Institute of Radiation Protection in China. The system collects information on the technical service provider, equipment and detector, radiation workplace (employer), radiation workers, and personal doses. A datasheet template linked to the NDR software is used to upload the data to the NDR database. Among other benefits, NDR is useful for establishing worker dose history, overexposure reporting, awareness and optimization, and contributes to data maintained by the IAEA, UNSCEAR, and other interested organizations. The development of a platform to retrieve old data and the harmonization of all processes between the regulatory body, the operator and service providers were identified as the main challenges. Other challenges include adding new organizations to the database through a graphical user interface (GUI), which can only be done through the DMS in MS SQL, and time-consuming manual data entry into the database. Planned future actions include involving the regulatory agency and other service providers in developing the modalities for implementing the NDR and involving the IAEA in restructuring the database organization using a DMS graphical user interface.

7 OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL, RESEARCH AND EDUCATION FACILITIES

The keynote lecture was given by the Netherlands and addressed a topic on ISEMIR-IR: A benchmark tool for optimizing radiation protection in industrial radiography. An overview was given on how industrial radiography technology works in shielded enclosure and on-site radiography. were reviewed. The occupational radiological protection in two situations was highlighted, with the potential for the most radiological protection in site industrial radiography. Typical 9 levels are possible in normal radiography with site radiography, and the highest dose rates result from blow-out and blow-in with a gamma source in the guide tube.

ISEMIR- IR is a web-based system established by the IAEA to maintain a database of occupational exposures derived from global surveys regularly conducted by the IAEA. The objectives of ISEMIR-IR are primarily to facilitate the implementation of ALARA practices and effective exposure management, and to contribute to minimizing the likelihood of accidents, e.g., by identifying precursors, user feedback, and lessons learned. The operation of the ISEMIR-IR system is overseen by a team of ISEMIR-IR consultants from various NDT stakeholders and the IAEA. Prior to the establishment of the ISEMIR-IR system, an Industrial Radiography Working Group (WGIR) was formed by the IAEA. The members of the WGIR were from all regions of the world according to the IAEA classification and included representatives from various stakeholders such as NDT companies, technical service organizations (TSOs), NDT societies, and NDT customers under the coordination of the IAEA. The goal of the WGIR effort was to meet the ALARA dose for normal exposure and the exposure risk for accidents. To this end, WGIR conducted a worldwide survey to gain insight into current occupational radiation protection practices at IR. The survey targeted regulatory bodies (RBs), operators (licenses), and industrial radiographers/radiographers (operators). The questionnaire topics were developed based on IAEA Safety Standards Series No. SSG-11, 2011) and IAEA-TECDOC -1747 (2014).

The results of the second global survey, conducted from October 2020 to January 2021, were presented and discussed. Currently, the questionnaires are distributed by email to Regulatory Bodies who forward them to the NDT companies, and they can also be accessed online. The survey is conducted annually, and the responses are collected and analyzed annually. For example, the number of survey responses received was 46 from RBs of 43 countries and 246 (42 countries) from NDT companies. The regional distribution for RBs was 7 (7 countries in Africa), 12 (10 countries in Asia-Pacific), 5 (5 countries in the Americas), and 22 (21 countries in Europe). The major limitation in the responses received was the incompleteness of the questionnaires. The status of the ISMIR-IR database supports three major types of analyses: first, occupational doses per radiation exposure for a given industrial radiologist as a function of personnel and operational characteristics. Others are benchmarking and trends over time (per radiation exposure in consecutive years). ISEMIR-IR also provides roadmap software that can be used by a NDT company to benchmark itself against other participating NDT companies in terms of radiation protection and workplace safety. Future developments include further promotion of ISEMIR-IR, revising the registration process (to be user-friendly and secure), improving the data collection process to provide more flexibility, and conducting a global survey in the fourth quarter of 2022. Conference participants were reminded that when using databases on individual doses, it is important to be aware that different, non-identical exposure situations are generally being compared because the causes of exposure to the average dose per individual may vary. For example, technicians with only one discipline (radiographic testing (RT)) are associated with a relatively higher dose than technicians with multiple disciplines (RT, ultrasonic testing (UT), and so on. Situations involving only RT technicians have relatively higher doses than situations involving no RT technicians. Doses are higher for high workloads (number of films, hours worked) than for low workloads (number of films, hours worked). Doses are higher when testing thick objects than when testing thin objects. From the exposure situations, the dose per radiograph/film was determined as the best metric for comparison.

The European Organization for Nuclear Research (CERN) has discussed occupational radiation protection in the operation of accelerators in the organization. The organization CERN currently has 23 members, including 7 associate members. Japan and the United States, as well as international organizations (EU, UNESCO), have observer status. CERN has international status because it is an intergovernmental organization based on international law. CERN is also recognized by its host states, France and Switzerland, through headquarters agreements with two countries, and by other member states in a protocol on privileges and immunities. This includes the right to establish rules necessary for the proper functioning of the organization and to ensure the safety of host countries. CERN works closely with host countries Switzerland and France on radiation protection and safety issues. In this context, a tripartite agreement was signed in 2010 between the host country authorities, the French Nuclear Safety Authority (ASN), and the FOPH (France), providing a legal framework for transparent and cooperative discussion of radiation safety and security issues at CERN with the host country authorities. The Radiation Protection Group of the HSE Unit is responsible for occupational radiation protection, individual dosimetry, environmental radiation protection, instrumentation, radioactive waste management, and services. Approximately 50 km of accelerator infrastructure and over 160 physics experiments, with all areas classified as radiation areas.

There is a radioactive ion beam facility (ISOLDE), a spallation neutron source (n-TOF). Several experimental halls for fixed-target experiments and radioactive laboratories. There is also a radioactive waste treatment centre and an interim radioactive waste storage facility. There are over 10,000 radiation workers, but the radiological risks are low, as more than 90% of the annual personal doses are below 100 μSv. Most of the personal dose on CERN receives negligible dose. Internal dosimetry has been a motivation for recent research and development work in a collaboration between CERN and the Institut de radiophysique (IRA) in Lausanne, Switzerland, via a Competency Centre for internal dosimetry. The ALARA approach at CERN defines the group according to the ALARA level based on a certain level of occupational dose, and monitoring is performed by the ALARA Committee. In Group 1, the ALARA level is defined based on criteria, and there are three levels (Level I - green, Level II - yellow, and Level III - red) depending on the individual dose equivalent level and the collective dose equivalent. Group 2 is based on radiological risk assessment, including accidents and incidents originating from RSO and HSE-RP, and there are three levels (Level I-green, Level II -yellow and Level III -red). The basis for Group 2 is ambient/equivalent dose, airborne activity, and surface contamination.

ALARA is achieved in accelerator design, work and dose planning, operational dose planning and monitoring, and material control and classification. The challenges at CERN are primarily in radiation monitoring because accelerator operation causes mixed particle fields (protons, neutrons, pions, photons) with energies over 16 orders of magnitude (thermal energies up to TeV) with pulsed time structures from nanoseconds to seconds. The radiation and environmental monitoring system (REMS) must cover 864 radiation monitoring channels due to the size and scope of the CERN facilities. The challenges have led to the internal development of a new generation of radiation monitoring systems for radiation protection, CERN Radiation Monitoring Electronics (CROME). The innovation is being rolled out continuously at CERN to replace all previous systems by 2028, and is also being tested elsewhere, with some important results highlighted.

U.S. presented on radiation protection for animal researchers. The National Institutes of Health (NHI) is a U.S. government medical research organization. It consists of 27 institutes and centres with 1600 ongoing clinical research studies. The number of staff is about 7300 scientists, physicians, and dentists, of whom about 2800 are involved in radiation research. The NHI has a license issued by the NRC to possess and use radioactive material. Nineteen (19) of NIH's 27 institutes/centres have an Animal Care and Use Committee (ACUC), and 2.1 million experimental animals are kept each year (95% are mice and zebrafish). Animal research is subject to U.S. Department of Agriculture: Plant Health Inspection Service regulations and must comply with the Animal Welfare Act and related regulations. NHI is accredited by the Association for Assessment and Accreditation of Laboratory Animal Care International (site visits occur every three years) and must follow the Guide for the Care and Use of Laboratory Animals (National Research Council) and U.S. Public Health Service guidelines. Available animal models include fruit flies, zebrafish, mice, rats, rabbits, guinea pigs, non-human primates, wood chicks, and pigs. The animal studies are conducted in collaboration between NHI researchers, animal caretakers, radiation safety staff, and management, all of whom help to ensure that the research can be conducted in a safe manner. Various radiation safety requirements were described, such as the use of time, distance, and shielding appropriate for surgery team, animal researchers, and animal care staff.

Radiation protection of staff is ensured through X-ray shielding training appropriate to their category (walls, barriers, lead aprons) and disused radioactive sources surveillance program. Other measures include assignment of an authorized user for each room, use of radioactive waste guidelines (sharps, cadavers), and dosimetry to document dose (whole body, collar, rings). Experience has shown that the average annual dose to surgery team is about 1.3 mSv, while for researchers and animal care staff is 2.5 mSv and 0.35 mSv, respectively. Environmental dosimeter readings are about 0.5 mSv, with no occupancy factor applied. The ALARA policy requires investigations at 10% and 30% triggers.

Japan discussed a data management system for radiation workers at all Japanese universities. Under the Law on Regulation of Radioisotopes, etc., on Industrial Safety and Health, persons working with radioactive materials or radiation equipment must keep certain records. These include individual radiation doses, health examinations, and education and training. Users from different departments or universities may use radiation and isotope facilities. Current issues related to radiation and radioisotope facilities at universities are discussed below. Complex employment systems (affiliation with multiple departments, dual staffing with outside parties).

- Aging facilities (most facilities in Japan were established in the last century)
- Shortage of budgets and administration staff

- Human error and missing information due to paper-based work
- University employees and students must be treated differently by law. Internal staff and students at some universities must follow Act on the regulations of radioisotopes etc while external staff/students are required to follow industrial Safety and health Act. Other staff/students must follow both Acts.

The presenter advocated the application of GSR Part 3 particularly, specifically Requirement 23 on cooperation between employers and registrants and licensees, to address such situations. The following actions have been taken to address the problems: nationwide networking of radiation protection facilities, use of a uniform format for information on radiation protection workers, and establishment of a system for sharing information on radiation protection workers among multiple facilities.

The overview shows that occupational radiation protection in industrial, research, and educational facilities is relatively mature and IAEA safety standards are applied. Nevertheless, high doses and occasional accidents do occur. The training of some radiation workers is inadequate, and in some cases improvements in harmonization of training and communication are still needed. The ISEMIR information system plays an important role in optimizing protection in industrial radiography, with the main challenge being to get the involvement of NDT industry.

8 OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR POWER PLANTS AND NUCLEAR FUEL CYCLE FACILITIES

The keynote lecture was given by the United Kingdom and dealt with radiation protection at the Sizewell B NPP: Thirty years of organizational learning with the assistance of ISOE. Sizewell B NPP was the first commercial PWR built in the UK and its construction of which began in 1987 and was commissioned in 1995. Due to UK's NPP fleet consisted of gas-cooled reactors, there was limited operational experience from PWRs and therefore Sizewell decided to join ISOE.

The operational experience is needed to support radiological design, commissioning, and radiation protection staff training and development. ISOE was established in January 1992 to improve the management of occupational radiation exposure at nuclear power plants through a comprehensive and regularly updated exchange of information and experience on methods to optimize radiation protection in the workplace. Sizewell B joined in the mid-1990s and remains the only UK utility. ISOE is the world's largest database on occupational radiation exposure at NPPs, a global network of radiation protection experts, and regularly hosts symposia and special meetings for radiation protection managers and regulators. ISOE also reports on analysis of current problems in operational radiation protection practice and on dose trends. ISOE also organizes benchmarking visits that allow ISOE members to share operational experiences and good radiation protection practices. The Sizewell B NPP has benefited from ISOE in several ways, including evaluation of the "R" in ALARA, response to unexpected events, continuous improvement, and benchmarking and analysis of performance indicators.

ISOE's future lies in its founding members taking on new challenges such as life extension and decommissioning. In addition, new countries are developing nuclear energy and will need access to experience in radiation protection operating experience and peer support. Therefore, the ISOE program should evolve to meet changing radiation protection challenges and reflect a more diverse membership. ISOE encourages new members and especially the participation of younger professionals who will lead our radiation protection programs over the next 30 years. ISOE is a unique source of worldwide radiological protection operating experience and peer support for nuclear power plants. The ISOE website now has an extensive library of documents and presentations containing professional experience, analysis, and innovations. ISOE membership continues to be critical to the development and progress of Sizewell B's radiation protection program.

Poland discussed the challenges of modern radiation protection in the implementation of nuclear power projects in the country, as studied by Polskie Elektrownie Jądrowe (PEJ) Ltd. Five studies related to radiation protection were presented, including initial measurements of natural background radiation. It was a two-year study to support the NPP project by complex measurements. The results show that the levels of background radiation are slightly lower than the average level in Poland. No significant increase in radioactive isotope concentrations was measured compared to the average levels. Secondly, the effects of NPP radiation during normal operation were studied. It is known that any nuclear power plant releases traces of radioactive effluents during normal operation. However, these emissions do not represent a hazard risk to the health of residents (estimated at 3.5 μSv/year (the limit is 0.3 mSv/year). This value is significantly lower than the average background radiation in Poland, which is about 2.4 mSv/year. Another study dealt with the optimization of the radiation protection parameter α, which describes the theoretical costs incurred when a single person is exposed to a dose of ionizing radiation equivalent to one sievert. The radiation impact of NPPs under accident conditions were also studied, showing that the risk of an accident during the operation of a nuclear power plant is very low. The last study dealt with the evacuation analysis, the J-value, which includes a profit and loss analysis. The J-value is a ratio between the costs of a relocation and the resulting gains. The conclusions of the analysis, conducted for the case of a nuclear accident representative of emergency planning, are that evacuation of residents is not justified if other intervention measures are included. Nor is relocation of people justified in any scenario.

Kazakhstan discussed occupational radiation protection as part of the occupational health and safety management system in uranium mining. The country is a leader in uranium mining by in situ recovery (ISR), (also known as in situ leaching (ISL)), with a production of 11.9 thousand tons, which is more than 24% of the world production in 2021. The country has 26 deposits divided into 14 clusters and employs about 4,500 radiation workers. The advantages of ISR over conventional mining methods are known to include lower mining costs, reduced environmental impact, and improved health and safety performance. NAC Kazatomprom JSC is the national operator for the Republic of Kazakhstan and has developed a safety culture that can be divided into four elements. These include leadership, behavioral safety, workplace safety (Vision Zero since 2018), environmental protection and radiation protection. The main radiation risk factors in ISR uranium mining are external exposure to gamma radiation, radioactive surface contamination of objects, and radon and radon progeny. Other factors include ingestion, contamination of wounds, and absorption and long-lived radionuclides in the air of work areas. A radiation monitoring program is in place to pre-assess radiation risks associated with radiation factors at each stage of the mining process. The program covers the types and routes of exposure, personal protective equipment used, workplace monitoring (production areas, sanitary facility boundaries), protection zone, residential area, and personnel monitoring. To share such national experiences, the IAEA established Information System on Uranium Mining Exposure (UMEX) and conducted a survey of worldwide workplace doses in uranium mining and processing. UMEX provided a snapshot of occupational doses in the uranium industry. The responses cover approximately 85% of global uranium production. The doses are consistent with international recommendations and represent good practice worldwide. The validity of the data collected was high, and analysis of the data revealed some areas for improvement. The results of the survey are included in the IAEA Safety Report SR 100. The need for SR -100 was aimed at supporting newcomers to the uranium industry who lack experience, resources, and independence. The newcomers need simple but clear guidance for all types of activities (life cycle approach), examples and simpler alternatives to the state-of-the-art solutions applied in the major uranium producing countries. Therefore, the objective of SR -100 is to assist regulatory bodies and industry operators in implementing a graded approach to worker protection. The second objective was to provide a basis for establishing a common understanding based on shared knowledge among the various stakeholders. To encourage wider application, the IAEA has developed a training course on occupational radiation protection in the mining and processing of uranium based on SR -100.

Japan discussed ten years at the Fukushima Daiichi Nuclear Power Station (FDNPS), then and now. The current situation at the FDNPS shows that a large area is designated for contaminated water tanks and debris storage. Fuel removal operations from the spent fuel pool began in November 2013, and by December 2014, all 1,535 pieces were removed. In Unit 3, where a hydrogen explosion occurred, removal of debris from the upper part of the reactor building and other work were completed, and installation of the fuel extraction cover was completed in February 2018. Removal of all 566 fuel assemblies was completed in February 2021. In Unit 2, the reactor building did not explode due to a partial opening of the wall and the release of hydrogen. The plan for removing the fuel assemblies from the spent fuel pool has been reviewed, and the removal of the fuel debris will be done in stages, starting with Unit 2. For Unit 1, the plan is to cover the entire building with a large cover and remove the debris remotely, using an overhead crane to remove the debris and heavy demolition equipment inside the cover. After debris removal, the plant floor will be decontaminated and shielded, and fuel removal equipment (fuel handling equipment and cranes) will be installed. The dose rate in the primary containment vessel (PCV) ranges from 4.1 to 9.7 Sv/h. On debris/solid waste containers, waste with a surface dose rate of less than 30 mSv/h is collected outdoors (including in tents); waste with a surface dose rate of more than 30 mSv/h is stored in containers and then in a solid waste storage area. The number of containers stored in the storage area is about 85,000, with about 54,000 debris (about 47,000 combustible and 7,000 non-combustible) and about 31,000 used protective clothing, etc. Volume reduction processing is planned. About 150 tons of groundwater naturally flowing from the mountainside to the sea flowed into the reactor buildings and became newly contaminated water. As of April 2021, the number of contaminated water tanks was 1047, the volume of water stored in the tanks is about 1.25 million m^3, mainly tritiated water (HTO), the average tritium concentration in the water is about 620 kBq/L, the total amount of tritium is about 780 TBq. The operating standard is 1,500 Bq/L, while the regulatory requirements are 60,000 Bq/L. As a result of various efforts, the external radiation dose has changed since December 2011. For example, the monthly average dose has decreased to below 0.5 mSv by December 2013 (at TEPCO) and almost zero by December 2016 (at a partner company). The collective dose also dropped to 40 man.mSv by 2017 and below 20 man.mSv by 2020. By March 2021, the maximum external radiation dose distribution for workers was 9.47 mSv/month with an average of 0.39 mSv/month for a total of 6736 workers.

The second presentation from Japan addressed recent developments in occupational radiation protection in Japan from a regulatory perspective. In April 2021, Japan announced the basic policy for handling treated water from the Fukushima Daiichi nuclear power plant. According to this policy, treated water near the power plant may be discharged into the sea if approved by national authorities. Japanese authorities requested IAEA assistance in monitoring and reviewing plans and activities related to the discharge of treated water. The IAEA conducted the review based on IAEA safety standards, which represent a globally harmonized high level of safety. The IAEA organized its review into five technical topics. These include government responsibilities and functions, key principles, and safety objectives and authorization Process (regulatory process, radiological environmental impact assessment, and characterization of the source term). Other areas include source monitoring and environmental monitoring (source monitoring and environmental monitoring) and public consultation and involvement of interested parties.

The mission's findings indicate that the legislative arrangements in Japan and the regulations on occupational radiation protection are generally consistent with the relevant IAEA safety standards. Based on the recommendations, TEPCO applied to the NRA on December 21, 2021, for approval to amend the implementation plan, which was granted by the NRA Commission on July 22, 2022. The documents containing the results of the NRA review are publicly available on the website in both Japanese and English.

Key messages in the session were the need to start monitoring before construction, the use of simulation tools to calculate impacts on normal and accident conditions, and the importance of incorporating existing standards into the assessment phase. A strong safety culture, including leadership and environment, radiation, etc., and safety reports are helpful to support newcomers to nuclear power generation. Graded approach was another key message from this session, which has huge implications not only for radiation protection but also for the environment, managing the amount of waste and requiring a comprehensive monitoring program. Cooperation at the international level is important. Another key message was the usefulness of accessing experiences from utility professionals with mature radiation protection programmes, such as ISOE members to set priorities and to learn from mistakes on operational aspects. This can be achieved by organizing staff benchmarking visits and by inquiring solution from other radiation protection professionals on ISOE platform in case of unexpected operational challenge. On the platform, standard benchmarking reports are available that allow plants to compare performance with similar NPPs. The benchmarking approach can also be useful in handling occupational radiation protection issues in life extension of nuclear power plants. Therefore, membership of ISOE can be fundamental to the development and progression radiation protection programme of any nuclear power plant facility. From a regulatory perspective, review missions against international standards are important and were generally supported. In brief, information to the international community is critical to focus attention on radiation protection, harnessing science, and technology, improving radiation protection, sharing knowledge and experience, and being prepared for new situations, pandemics, wars, etc. Some experiences from the contributions have shown that radiation protection is only one part of the overall safety in uranium mining, in addressing the challenges related to spent fuel management (backend of the fuel cycle), and in radiation protection related to wars (feedback from managing the aftermath). The fast breeder test reactor is a different technology, but similar radiation safety challenges were another experience.

9 OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO NATURALLY OCCURING RADIOACTIVE MATERIAL, RADON, AND COSMIC RAYS

The keynote paper was on NORM, radon, and cosmic ray radiation protection in USA, delivered by the US. ICRP radiation protection recommendations and NCRP Report No. 160 (Ionizing Radiation Exposure of the Population of the United States) were discussed. Matters related to radiation protection are governed by federal agencies. These include the Environmental Protection Agency (EPA), the Nuclear Regulatory Commission (NRC), the Department of Energy (DOE), the Department of Labor-Occupational Safety and Health Administration (OSHA), the Department of Transportation (DOT), and the States/Conference on Radiation Control Program Directors (CRCPD)/Social Science Research Solutions (SSRs). However, most radiation protection falls under the regulatory authority of the states, including EPA, Federal Emergency Management Agency (FEMA), DOE, NRC and Food and Drug Administration (FDA), US Department of Labor, and DOT. The regulatory framework was described and related issues are addressed by EPA, OSHA, DOT, and States/Organization of American States (OAS)/CRCPD. Other reference documents reviewed and discussed included the National Academy of Sciences (NAS)report - Biological Effects of Ionizing Radiation (BEIR) VI, UNSCEAR 2008 Vol. 1, Annex B, studies on the epidemiology of uranium mining, and a WHO handbook on indoor radon.

Some of the important regulatory requirements were highlighted. EPA has set the limit for drinking water at 0.19 Bq/L. The results of surveys of radon concentrations in basements in the United States were presented. For example, as of 8/4/2021, there were 19 homes with more than 3.7E4 Bq/ m^3 and one home has the current state record of more than 6.48E5 Bq/ m^3. US EPA has set the radon concentration limit at 148 Bq/ $m^3$for individuals and families, home buyers and sellers, and builders and contractors. The radon concentration limit is 148 Bq/ m^3 for individuals and families, home buyers and sellers, and builders and contractors. The WHO handbook also includes a reference level for radon concentration of 100 Bq/ m^3, but it should not exceed 300 Bq/ m^3. Exposure of the public, aircrew, and space personnel to cosmic rays in the United States was presented. Thus, public exposure ranges from 40 to 88 nGy/hour, while space mission exposure ranges from 0.2 to 200 mSv. The limit for astronauts as per National Aeronautics and Space Administration (NASA) proposed radiation health standard is 600 mSv, while the limit for U.S. aircrew is 20 mSv/year, as established by the Federal Aviation Administration. The dose limit for pregnant flight attendants is 0.5 mSv per month.

Recommendations and regulations from EPA, NRC, and OSHA contain different limits for radon exposure. EPA sets the limit for radon (population) at 148 Bq/ m^3, while the ICRP recommends a limit of 300 Bq/ m^3 for the population. The NRC sets the limit for radon (workers) at 1,100 Bq/ m^3, while OSHA sets a limit of 3,700 Bq/ m^3 for workers. A revision of the radiation protection regulations was suggested. Different federal agencies and states take different approaches to regulating NORM /TENORM, radon, and cosmic radiation, and radiation protection standards and regulations are not uniform. There is no clear federal agency with jurisdiction over NORM /TENORM. Radon testing in homes, schools, and workplaces is a priority. Dose is dose and is directly related to risk, whether it is natural or human-made radiation, and a balance must be struck between government, industry, the public, and the media.

The Netherlands discussed the NORM X symposium and the circular economy - “Radiological features versus economical use”- Professionals' viewpoint. The discussion reflected on the theme of NORM X which was 25 years of NORM Symposia “Future: Residues in a Circular Economy”. Examples of the circular economy were provided, which included phosphogypsum used in ceramic tiles, and winter chickpeas grown with fertilizer. Another example was slag from thermal phosphorus production used in dike construction. A total of 205 participants from 38 countries attended NORM X, and 25 years of NORM symposia has witnessed important memories. The period has been built on the foundation of 25 years of hard work and great progress made since 1997 have resulted in a legal framework now in place in all countries. There is now an active and vibrant NORM community, and there is more to do to attract and develop the next generation. It is explicitly recognized that optimization has potentially far-reaching implications. Economical drivers in decision making are not new to radiation protection, because although radiation protection focuses on science and values, economics is considered part of optimization. Optimization is one of the pillars of radiation protection and requires the involvement of all stakeholders. However, the challenges of a circular economy must be addressed. The government must develop a clear policy to implement the circular economy. In addition, residue producers, service providers and environmental authorities need to be trained and sensitized. Furthermore, upgrading needs to be promoted to improve product-specific resources. Laws and perceptions could be changed if real economic resources and production of key materials for clean energy projects are achieved. There are also challenges in regulating NORM industries and turning them into opportunities. Among these, is the application of graded approach to regulating industries that process NORM and NORM residues and addressing radiological and non-radiological hazards in an integrated manner. Another challenge could be the reuse and recycling of NORM residues to avoid the need for new materials (circular economy) for long-term management and disposal. NORM Measurement techniques have improved significantly, but the ability to evaluate and interpret results still needs to be improved, which can be difficult if one does not have experience. The lack of accredited laboratories performing NORM measurements is a problem in some countries, considering that metrology and sampling play a crucial role in the circular economy. The chemical composition of NORM should also be considered when characterizing NORM, and in many cases, industries using NORM do not have the appropriate expertise within the company but rely on outside consultants.

Examples of safe use of NORM residues were used to discuss a number of issues of concern. These include further guidance on transportation that will be provided in a new safety report. The many interested groups such as IAEA, ICRP, IRPA, EC (RadoNORM), HERCA WG-NAT need to coordinate so that the circular economy benefits all. Some examples of great technical innovations were given, but much remains to be done, e.g., the use of drones for site characterization, the use of fiberglass epoxy resin in geothermal projects, etc. In addition, there are IAEA initiatives working to improve information dissemination, and ISEMIR-N is an important platform for professional cans in various industries with NORM. A summary of the NORM X symposium indicated that a new era is dawning for the use of residues in the circular economy to balance radiological features versus economic use. Finally, it was announced that the next NORM XI symposium will be hosted by the Ghana Atomic Energy Commission (GAEC) in collaboration with the Ghana Association for Radiation Protection (GARP) and the African ALARA Network (AFAN) to be organized in 2025.

Germany discussed dosimetry measurements and calculations for aircrew. Protection from galactic cosmic radiation on Earth is achieved through shielding by the geomagnetic field and Earth's atmosphere. However, the interplanetary magnetic field varies as a function of solar activity, which has been the reason for numerous cosmic ray studies that have been presented. In one study, the cosmic ray fluence rate was calculated using FLUKA Monte Carlo codes for a period near solar minimum around 16.4 km, in polar regions, and in equatorial regions. The relative contribution to the H*(10) rate by muons, electrons, photons, protons, and neutrons was calculated for different settings for the period 2015 (smaller solar maximum) and for Zugspitze region in Germany. In January 2008, EPCARD.Net, which is based on ICRP 60, was used to calculate the effective dose for flight routes from Munich, New York, Sydney, and Kuala Lumpur for the solar minimum period. Another measurement method is the worldwide network of neutron monitors (NMs). The NMs provide count rates with very high precision (several thousand counts/minute), but no information on fluence, energy, and dose of neutrons. Radiation maps at flight level are provided by SiGLERT, a real-time version of the SIGLE model that calculates dose rates during the German Longitudinal Election Studies (GLEs). During quiet periods, dose rates are calculated by EPCARD.Net (Galactic Cosmic Ray) by selecting an altitude. Some measurements aboard aircraft were also presented. A study performed with the aircraft NASA airborne science ER -2 included 3 flights in June 1997 (solar minimum) with 12 Bonner spheres on board at a maximum altitude of 21 km. The neutron integral quantities Φ and H*(10) were measured at different locations. At a cut-off of 12 GV and an altitude of 20.3 km, H*(10) was 1.06 µSvh-1, while at a cut-off of 0.8 GV and an altitude of 20 km, H*(10) was 8.5 µSvh-1. Another study was conducted by REFLECT (research flight of EURADOS and CRREAT) to compare 17 radiation dosimeters aboard Embraer Legacy 600. Three concluding observations were made, among others. First, aircrew is considered as a group of workers receiving one of the highest annual effective doses. Second, the personal dose from cosmic rays to aircrew is routinely calculated using various computer codes that are validated by measurements and code comparisons. Third, there is no single personal dosimeter that can simultaneously and truthfully measure all components of cosmic radiation on a routine basis.

Austria discussed radon in the workplace: framework, practical issues and challenges. Radon protection in the workplace is important in various aspects. Radon activity concentrations in water reservoirs, underground workplaces and schools, kindergartens or town halls have been proven. For example, measurements of radon concentrations in about 350 schools, 800 kindergartens and 440 administrative buildings (mainly in Upper Austria) showed that they are about 20% above the reference value of 300 Bq/m³. According to the international framework, a strategy for protection against exposure due to ^{222}Rn in workplaces, shall be established including the establishment of an appropriate reference levels for ^{222}Rn. The reference level for ^{222}Rn shall be set at a value that does not exceed an annual average activity concentration of ^{222}Rn of 1000 Bq/m^3, with account taken of the prevailing social and economic circumstances. Employers shall ensure that the activity concentration of ^{222}Rn in workplace are as low as reasonably achievable below the established reference level and shall ensure the protection is optimized. If despite all reasonable efforts by the employer to reduce activity concentration of radon, the activity concentration of ^{222}Rn in workplace remains above the established reference level, the relevant requirements for occupational exposure in planned exposure situations shall apply. According to ILO Convention 115, these workers are occupationally exposed to radiation and have recognized rights and obligations in this regard. Other reference documents. IAEA SSG32, IAEA SRS -33, IAEA SRS -98 and IAEATECDOC-1951 apply to occupational radiation protection from radon. The EU requires radon measurements at workplaces in priority radon areas and at certain workplaces identified in the National Radon Action Plan. The EU also requires that workplaces with radon concentrations above the RL (after remediation and optimization) must be reported to the competent authority and graded approach applies to occupational exposure. The exposures shall be kept under review where exposure of the workers is less than or equal to 6 mSv per year. Where the exposure of workers is liable to exceed an effective dose of 6 mSv per year, the situation shall be managed as a planned exposure situation and appropriate requirements, such as dose limits apply. Some practical implementation issues were discussed, such as the scope of the regulation, definitions of exemptions and requirements for exceeding the RL, and quality assurance. Implementation challenges identified included testing practicability of the regulation, workflows, interaction, communication, and ensuring compliance.

10 OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

The keynote presentation on the topic of overview of occupational radiation protection in medicine was given by the United Kingdom. While radiology and computed tomography staff are usually in a protective cubicle, the situation is different in interventional radiology, interventional cardiology, and mobile fluoroscopy, where personnel are in the X-ray room. In interventional and other fluoroscopic procedures, the X-ray tube is placed under the couch to reduce the dose to the upper body. Interventionalists must be near the patient to operate the equipment, and in some procedures their hands are near the edge of the x-ray field. Typical scatter dose for cardiology procedures without shielding ranges from 10 to 100 µGy, with a maximum on the body (100 µGy) followed by the legs (80-90 µGy). Keeping patient dose low is key protection to x-rays. Occupational radiation protection can be provided through the use of personal protective equipment (PPE), lead aprons, and thyroid collars, and staff wear a 0.25 mm lead apron, and some models have 0.5 mm lead in the front. Another useful radiation protection measure is the use of lead acrylic shields suspended from the ceiling to protect the head and eyes, and lead blankets attached to the couch to protect the legs. It is also important to protect the eyes of interventionalists as they are exposed to X-rays coming from below and from the side. Models of lead glasses often do not provide good protection against scattered radiation from the side and below. Their design needs to be improved to close the gap beneath the eye wear lens and the cheek. Dose monitoring in radiology is performed using the Hp (10) quantity on the body to estimate the effective dose, and the dose limit is 20 mSv. The eye lens is measured using the Hp (3) quantity adjacent to the eye; the dose limit is 20 mSv. Skin dose is measured using the Hp (0.07) amount on the fingers on an average area of 1 cm2; the dose limit is 500 mSv.

In nuclear medicine, staff are exposed while attending patients (as they become radiation) sources). Accumulation of doses from routine tasks can result in staff receiving annual doses of several mSv. The patient should be planned, and routine communication should occur prior to administration. For the staff handling vials and syringes containing radiopharmaceuticals, high doses may reach fingers during administration and injection. Reduce external exposure to staff preparing radiopharmaceuticals by working behind benchtop shields and appropriately handling and disposing of shield used for syringes and vials. Protective clothing (gloves, aprons, etc.), and work shall be performed over trays lined with absorbent material to collect spills. Other measures include monitoring work areas after handling radioactivity and regular self-monitoring by personnel.

For radionuclide therapy, ICRP Publication 140 contains appropriate recommendations. Radiopharmaceuticals accumulate in certain tissues, and ß-particles can deliver high local doses. Iodine-131 therapy is mainly used to treat thyrotoxicosis (hyperthyroidism) (400-600 MBq) and some types of thyroid cancer (several GBq). Protection measures include the use of shielding in treatment rooms for inpatients, the use of mobile shielding in certain situations, and measures to reduce contact with other people, especially children and pregnant women. Large dose gradients occur at the hand. Dose can vary from 0.05-3 mSv/Bq (99mTc), 0.3-8 mSv/GBq Fluorodeoxyglucose (FDG) (18F) PET, and the magnitude of the dose depends on the level of protection. Tungsten shields are used for vials and syringes, while automatic dispensers can be used for PET and other radiopharmaceuticals, but they are expensive. Finger dose during 90Y therapy can easily exceed the finger dose limit, and blistering of fingertips has occurred in the past. Individual 90Y monitoring is done with finger TLDs on the tips of the thumb and first three fingers of each hand. Treatments are performed in concrete bunkers with maze entrances, and personnel should always be outside the bunker when a patient is being treated. Engineering controls, such as interlocks, prevent accidental access. In brachytherapy, radiation sources are placed inside the body near the tumor. Modern brachytherapy treatments are performed with remote afterload systems that load high-dose rate sources into catheters when staff are not present in the room. Manual afterload brachytherapy is still used in some centres. Radiation therapy staff are personally monitored in the event of an incident.

USA addressed radiation protection and safety in veterinary medicine. The paper focused on IAEA Safety Report No. 140 (Radiation Protection and Safety in Veterinary Medicine) and the key aspects of radiation protection specific to veterinary medicine that are included in Safety Report No. 140. Veterinary medicine mimics medical procedures for humans. Worker protection is extended to animal owners and caretakers. Imaging and therapy may not be performed in a veterinary clinic, but at a remote location. Doses of animals that have received radioactive material may require quarantine of the animal. Similar procedures for disposal of radioactive material may be required. Safety and security interfaced with radioactive material may need to be considered. The IAEA safety report was developed to prevent unnecessary exposure of workers to radiation. The BSS recognizes radiation used in veterinary medicine as a potential exposure pathway. Classified radiation sources used in veterinary medicine as planned exposures. The structure of the safety report is consistent with human medical applications in human medicine, i.e., diagnostic imaging, nuclear medicine, and radiation therapy. In radiology, radiation protection includes personal protective equipment (aprons, thyroid shield, gloves, eye protection during fluoroscopy). Nuclear medicine uses ^{99m}Tc for cats/dogs/horses, while therapy uses ^{131}I for cats and ^{117m}Sn for dogs/horses. For internal dose assessment of ^{131}I, 1 g is used for litter/excreta inhalation and contact, 1 ml for licking itself, and 1 ml for saliva transfer. In the case of external dose rate assessment, animal handling, exposure, handling of biological animal waste, and storage. For radiation protection issues in radiotherapy workers should not be in the room during treatment and may need to post notices and place restrictions in areas not defined as radiation work areas. Regarding training, many veterinary services staff are not trained in radiation protection. Knowledge, skills, and competencies should be identified in relation to national regulatory requirements, justification and optimization of procedures, and communication with animal owners. Specific competencies are required for veterinarians working in interventional radiology, nuclear medicine, and radiation therapy. The example of an animal owner's neck contaminated with ^{131}I was used to demonstrate the importance of radiation protection and safety in veterinary medicine. The estimated skin activity of the animal keeper was 18 kBq, and the equivalent dose of 27 mSv on the affected area of 4 cm2 with an estimated dose of 1.4 mSv.

Switzerland discussed the establishment and implementation of eye lens dose monitoring and protection program. The motivation for this work was the challenging nature of eye lens dosimetry. The objective of this work was to provide recommendations concerning eye lens monitoring in the medical field. The use of dedicated eye lens dosemeter is the most reliable technique. It must be calibrated on a phantom and positioned as close as possible to the eye lens under protection, and another dosimeter is needed. According to Swiss legislation, the eye lens dose can be determined with a dosimeter under the eye lens protection or above the eye lens protection. It is recommended to measure eye lens dose be measured as part of routine monitoring when the dose is > 5 mSv (IAEA TECDOC 1731), > 15 mSv (single year), or > 6 mSv (consecutive years) (ISO -15382). The IRPA guidelines recommend a survey in the dose range of 1to 6 mSv and routine monitoring when the dose > is 6 mSv. The results of the survey, which included 1329 eye lens dose measurements in 40 countries in 6 European countries, identified staff who should participate in mandatory routine eye lens dosimetry (gastroenterology and orthopaedics) should participate in mandatory routine eye dosimetry with dedicated eye lens dosimeters (angiology, interventional cardiology, and vascular surgery). The 90th percentile dose values for the staff group were 7.1 (gastroenterology), 6.6 mSv (interventional radiology), and 7.4 mSv (orthopaedics). Other values were 21.1 mSv (angiology), 31 mSv (interventional cardiology), and 26.2 mSv (vascular surgery). An example of an optimization process in eye lens dosimetry in Switzerland was presented.

In general, the discussion in the session demonstrated that by far the greatest potential risk to workers is interventional fluoroscopy procedures. While tissue reaction cannot be ruled out in patients, workers are also at risk for stochastic effects. Many good practices can and should be taught to workers. The need to formalize feedback and knowledge sharing was also evident in the discussions.

11 OPTIMIZATION IN OCCUPATIONAL RADIATION PROTECTION

The keynote lecture addressed optimization of protection, the cornerstone of radiation protection, and was delivered by Belgium on behalf of the European ALARA Network. The keynote lecture started with an overview of different applications of ionizing radiation, followed by an explanation of the basic principles of radiation protection according to ICRP. Three levels were highlighted in the use of dose limits: acceptable risk, tolerable risk, and unacceptable risk, where optimization is essential to reduce the level of individual exposure from tolerable risk to acceptable risk. The dose limit establishes the maximum level of tolerable risk above which the risk is unacceptable. During the optimization process, the concept of ALARA is applied, which was introduced by the ICRP in 1951. ICRP Publication 103 of 2007 ALARA is defined as Low as Reasonably Achievable, taking into account economic and societal factors. The acceptable level of risk depends on many factors, including the exposure situation, societal considerations, economic considerations, and other risks. Other factors include judgments, processes (procedures), and technical considerations.

The ALARA process can proceed in the following order. Description of exposure situation, review of input data required for dose assessment (analysis of doses), initial dose assessment (identification of protective measures that can (or cannot) be implemented), ALARA analysis (evaluation of effectiveness of protective measures), ALARA synthesis – operational follow-up, review of process (selection of protective measures (identification of decision criteria, ranking of measures)), and finally follow-up and experience feedback – performance analysis, analysis of gaps and errors, proposal of corrective actions (sensitivity analysis). If the last phase is not successful, the ALARA analysis is repeated. Industrial risks, environmental risks, safety risks and socio-economic aspects are also considered when planning optimization. Safety culture – ALARA culture is also an important part of the optimization process. While the concept of safety culture is understandable, ALARA culture is related to safety culture and is influenced by attitudes and behaviors, stakeholder engagement and participation, and radiation risk awareness. Stakeholders to be involved include competent authorities, licensees, manufacturers, suppliers and designers, and radiation protection professionals. Other groups include professional associations, exposed workers, and the public. Education and training of stakeholders to achieve both a good scientific understanding of risk and a good understanding of risk perception. This means that a good balance between safety and risk is needed to facilitate the optimization process.

The benefits of optimization in terms of reference, mindset, and attitude are highlighted. This includes feedback from various organizations in the field, EAN, ISEMIR, ISOE, UNSCEAR, EMAM, EFOMP, etc., confirming a reduction in individual dose. An example of dose reduction is the UNSCEAR report (2020-2021), where the average annual effective dose for the period 2020-2014 from all human-made sources is about 0.5 mSv, a substantial decrease from 1.7 mSv 40 years ago. The concluding remarks discussed the following benefits of the optimization approach: dose reductions can be achieved in various areas of ionizing radiation application, and optimization promotes risk awareness to support safety, safety culture, and stakeholder engagement. It also promotes good governance, balanced judgment, and enables optimal use of resources. Therefore, optimization is a cornerstone of protection and radiation protection.

The ICRP discussed reasonableness and occupational exposure: an ICRP perspective. The presenter began with an overview of the ICRP's current protection system (protection principles, i.e., justification, optimization, and limitation). The principles also apply to dose criteria (reference levels, dose constraints, dose limits) and requirements (assessment, accountability, transparency, involvement). The presenter reminded conference participants of the ICRP definition of occupational exposure as "radiation exposure at work," which can reasonably be considered the responsibility of the operating management. Not all exposed workers are considered occupationally exposed to radiation because the level of exposure does not necessarily matter. Another element to consider is the nature of the exposure situation (planned, existing, emergency). The current internal reflection about reasonableness and tolerability are contained in the ICRP Task Group 114 report. The ICRP model of risk tolerance was presented in ICRP Publication 60, but an interesting question is whether this model is appropriate for all exposure situations. As is well known, the ALARA level is achieved by optimizing the dose from a selected value below the dose limit to a value just above the acceptable residual risk. In planned exposure situations (PES), occupational exposure is a matter of exposure level, since the potential for exposure can be high. The most important requirements are the implementation of all elements of the radiation protection program. For occupational exposure, adequacy is achieved by optimization using dose constraints (ICRP Publication 103, ICRP Publication 101 (Part 2)). Tolerability, on the other hand, is achieved using occupational dose limits. In emergency exposure situations (EmES), a worker may be occupationally exposed, but the ICRP introduced the concept of responder (different status and preparedness). In EmES, adequacy is achieved by optimization against reference values. Distinction on site/off-plant and provision of reasonable working and housing conditions. For reasonableness, the recommended maximum reference level of 100 mSv applies, and possibly some exceptional circumstances, e.g., life-saving measures.

In existing exposure situations (ExES), a worker may be occupationally exposed even if this is not stated. It is more about the exposure conditions than the exposure level. Protection should be adapted (requirements and implementation), which imply reasonableness. Reasonableness is achieved through optimization using reference levels, recognizing that a multi-hazard situation can be challenging because the radiological risk is often not predominant. In this case, a graded/adjusted approach is required. Examples of a graded approach to ExES include starting with common occupational health and safety standards and integrating radiological protection measures as needed, and starting with collective protection and continuing with individual protection as needed. Tolerability in ExES, care is taken to ensure that the risks are low and therefore that there is no real prospect of emergencies or tissue reactions. Dose limits may be useful for regulatory purposes but are not required from a radiation safety perspective. Other considerations are reasonableness and tolerability based on ethical values Reasonableness and tolerability based on ethical values, and the development of a radiation safety culture in the workplace. As appropriate, dosimetric criteria should be subject to restrictions, incentive tools for protection, or benchmarking. More importance should be assigned to qualitative considerations (well-being, deliberative process, trustworthiness, societal considerations, etc.).

Norway addressed the application of 3D hazard simulations, extended reality (XR), and artificial intelligence (AI) to optimize the use of humans and robots in nuclear environments. The presenter presented the services and work areas of the Institute of Energy Technology (IFE), which include safety. IFE hosts the OECD Halden HTO project (formerly OECD HRP), which is designated as the IAEA's first international collaboration center in the field of nuclear decommissioning. The center conducts research that facilitates the digital transformation of nuclear power plant decommissioning and promotes international knowledge exchange. These research activities apply radiological hazard modeling using computer codes. To promote such research activities, the Norwegian Nuclear Energy Action Plan was established in 1995. This plan is Norway's main instrument for nuclear safety and security cooperation in Russia, Ukraine, and other Eurasian countries. It is funded by the Ministry of Foreign Affairs, while the Norwegian Radiation and Nuclear Safety Authority (DSA) is responsible for administering the plan.

The IAEA presented feedback from completed ORPAS missions. ORPAS was first developed in 2001 and formulated in 2003 with the IAEA/ILO International Occupational Exposure Action Plan. ORPAS are peer review missions to assess occupational radiation protection at the request of a Member State. The main objective of ORPAS is to determine whether the host country has adequate arrangements for occupational radiation protection and whether these arrangements are functioning to the extent that practical arrangements for worker radiation protection are effective and generally optimized. ORPAS provides a cross-cutting review of the regulatory framework for occupational radiation protection and the application of the requirements in all facilities and activities using radiation technologies in the host country against the relevant IAEA safety standards (mainly GSR Part 3, GSG 7, GSR Part 1 (Rev.1) and GSR Part 4). ORPAS is designed to provide such a peer review service and is a family of other IAEA peer review services. These services include the Integrated Regulatory Review Service (IRRS), Education and Training Appraisal (EduTA), Integrated Review Service for Radioactive Waste and Spent Fuel Management Decommissioning and Remediation (ARTEMIS), Emergency Preparedness Review (EPREV), Integrated Nuclear Infrastructure Review (INIR), and Transport Safety Appraisal Service (TranSAS), etc. Details on ORPAS can be found on the collaborative platform IAEA ORPAS. This platform includes information on the review process, how to apply, how to conduct the self-assessment, calendars/references, questionnaires, a list of completed missions, and global reports. The ORPAS strategy for the missions (focusing on operators, technical service providers, and regulatory bodies) is also detailed on the platform. The ORPS mission deliverable is the ORPAS mission report. The general findings of the ORPAS missions for optimization have been summarized. These include that, with few exceptions, occupational radiation protection arrangements in the Member States are in line with IAEA safety standards (GSR Part 3 with 52 overarching requirements and GSG-7 guidance). The ORPAS missions have been of great benefit to the Member States. The missions led to the development/updating of laws, regulations, and guidance in occupational radiation protection in the Member States. Radiation protection programs of operators were improved. Improvements were also made in technical services such as calibrations and individual monitoring, quality management systems, harmonization of quantities, and increased capacity. The flexibility of the ORPAS program also addresses the specific needs of member states. The scope of appraisal could cover some or all aspects of a country's occupational radiation exposure arrangements. In addition, the assessment can cover member states with different levels of use, i.e., countries with nuclear facilities, countries starting with nuclear facilities, countries without nuclear facilities, and countries in a new phase of implementation. To increase Member State ownership of their recommendations and proposals. ORPAS is exploring opportunities for joint missions, and ORPAS is becoming more visible (70% increase in the conducted appraisals in the last 5 years). Occupational exposure requirements in planned, emergency, and existing exposure situations, as well as optimization, which is one of the more difficult concepts and play a central role in radiation protection, are among the important challenges being experienced by member states.

12 TECHNICAL SERVICE PROVIDERS IN OCCUPATIONAL RADIATION PROTECTION

The keynote lecture on "What improvements are needed for technical service providers in occupational radiation protection?" was given by Belgium. An overview of the quantities used in personal dosimetry and the accuracy required was given, and the limitations were discussed. Occupational dose limits are expressed in protection quantities (effective dose, E, equivalent dose in organs, HT). However, effective dose is not measurable. Operational quantities, measurable personal dose equivalents, are used to express personal dose at Hp(d), where d is 10, 3, or 0.07 mm.

Large uncertainties are allowed in personal dosimetry. A factor of 2 is not very stringent and will cause clients to doubt the performance of the dosimetry service. Large uncertainties are allowed because of other large uncertainties in risk assessment, since Hp (10) provides only an estimate for E. Dosimetry services strive for 5% better results to improve confidence, since any uncertainty gained is positive even for very small doses. Thus, there is still a need to improve dosimeter performance. Should this be done by narrowing the trumpet curve or by narrowing the type test criteria (IEC 62387)? Regarding sources of uncertainty, there is no perfect dosimeter for measuring Hp (10). IEC 62387 specifies requirements for type testing, such as a coefficient of variation of 5-15%, a nonlinearity of about 10%, and an energy/angle response of -30 to +70% for the energy > 56 keV. In addition, there is a calibration uncertainty of about 6%. Therefore, any improvements in personal dosimeters should focus on energy and angle. In general, personal dosimetry services have no problems achieving the Trumpet curve criteria. The EURADOS comparisons give a good picture of the performance (mainly of the European services). In an IC2016 intercomparison involving 103 dosimetry services with 2256 irradiated dosimeters, the following results were obtained: 7% of data points were outside the trumpet curve, 87% of services had a maximum of 2 outliers (ISO 14146 criterion), and an overall mean response of 0.98 compared to the reference value.

Despite the good results, there is room for improvement because only standard fields are used in the interlaboratory tests, where the influencing factors are limited as in real fields. For extremities and neutrons, worse results were obtained in the EURDOS comparison (IC 2019), 6% of 68 participants were outliers for gamma irradiations, and 58% of the results were outside the trumpet curve for Kr-85. Improvements are needed at low energy and high angles. Active personal dosemeters (APD) are technologically suitable as legal dosemeters. Reliability is good because fewer results are lost if the dosimeter fails or is lost. Radiological characteristics are also comparable and even better than passive dosimeters. However, approval, quality, and calibration are important because they are not intended for stand-alone use. They must also be approved and regularly calibrated for dosimetry and may be less suitable for certain areas such as hospitals (low energies, beta or pulsed radiation). Legislators should be prepared to approve APD and hybrid dosemeters. In future, computational on-line computational dosimetry is expected in the future. Physical dosimeters will no longer be needed, as the use of tracking camera fast computational codes, flexible phantoms, machine learning, etc. is expected. For neutrons EURADOS ICn 2017 12 services had more than 2 outliers, with 22 systems requiring workplace field information to able to estimate doses. Improvements are needed in this area.

When correction factors are used, measured doses are sometimes not a good estimate of the amounts needed such as in extremity dosimetry, nuclear medicine, when using lead aprons, lead glasses etc. Correction factors can make an order-of-magnitude difference because they are not applied consistently, because it is not clear who should apply them, which factor to use, whether the legislation allows it, or whether it is up to the service provider or user to decide. It is also unclear what role dosimetry services, regulators, radiation protection experts, etc. play in the application of correction factors.

National dose registries are established at the country level to record all occupational doses, follow-up, and statistics. There are many differences between countries (annual/quarterly/monthly submission by dosimetry services, all doses, only whole-body doses and/or APD only, categorization of workers - type of work, lost dosemeter recordings, many countries without NDR). Harmonization could be beneficial and ISO / CD 24426: format of input data for statistical description of dose records of individuals monitored for occupational exposure to ionizing radiation could be helpful.

The impact of the new ICRU operation quantities will require that technical service providers, international standards, and dose records and registries be adapted to them. Radiation safety practices may be affected, particularly doses for low-level energy X-rays, as less overestimation of effective dose can results and measured operational dose will decrease. Internal dosimetry uses direct measurements or indirect measurements. Calculating doses based on measurements is not straightforward, as knowledge and training are required. There are a much smaller number of technical service providers, often only one per country or for local customers, such as in nuclear power plants. There are also often fewer people with knowledge in internal dosimetry, and comparisons of calculations show large differences. In internal dosimetry, fewer intercomparisons are performed, and calibration phantoms and traceability are also needed. In summary, technical service providers for external dosimetry perform well in intercomparisons, but reducing uncertainties will help increase confidence in dosemeters. Caution should be exercised when moving to APDS for legal dosimetry, as approval procedures should be followed. No uniform application of factors. Technical services for internal personal dosimetry need more intercomparisons and traceability/phantoms and sufficient training for internal dosimetry calculations. There is much work to be done for new operational quantities to be fully utilized.

The UAE addressed the regulatory requirements for authorizing radiation safety services in the country. The Federal Authority for Nuclear Regulation (FAHR) is a regulatory agency for the peaceful uses of nuclear energy, established in 2009 by Federal Decree No. 6 of 2009. The country is characterized by a diverse industry, and there are no regulations governing the provision of technical services. Current technical service providers provide services based on the experience they have gained in their countries of origin. Following a study of international and domestic practices in the provision of radiation protection services, FANR decided to authorize the provision of radiation safety services using a regulation on graded approach. It is expected that the service providing market in UAE will be defined. The provision of radiation protection services will lead to quality outcomes that will facilitate regulatory oversight and ensure that clients are not able to compromise with the services provided. Current technical service providers include: radiation safety consultancy, maintenance, measurements, and evaluation of dose to workers or the public. Other services include calibration, testing, remediation, medical physics, radiation measurements, and other radiation safety services as may be determined by the regulatory body. The following authorization requirements are necessary. The service provider must be a legal entity registered in the economic department in UAE. A list of radiation services and a list of appointed experts should also be provided. Equipment, methodology, and protocols for provisional services and valid accreditation are required. Expected challenges include establishing criteria for experts providing services to clients and enforcing the application of ISO standards in accordance with the country's metrology requirements.

Brazil addressed the National Laboratory of Metrology of Ionizing Radiation Metrology in the Country - Experiences and Challenges. The laboratory began operations in 1970 and joined the IAEA/WHO network of Secondary Standard Dosimetry Laboratories (SSDLs) in 1976. in 1986, the Instituto de Radioprotecao e Dosimetria (LNMRI) joined the International Committee on Radionuclide Metrology (ICRM) and participated in the first key intercomparison organized by the BIPM using a primary method of calibrating the activity quantity. The Instituto nacional de Metrologia (NMETRO) promoted the laboratory as a designated institution for ionizing radiation metrology. The laboratory performs primary standardization for air kerma (radiotherapy and radiation protection) and secondary standardization in radiation therapy (Co-60, X-rays) and radiation protection (Co-60, Cs-137, X-rays).

Ionizing radiation metrology has implications for occupational dose, effective cancer therapy, accurate medical imaging, new radiopharmaceuticals, and safe disposal of radioactive waste. It is well known that safe and accurate measurements require no break in the traceability chain from definition of the quantity, realization, use of accredited calibrations to perform internal calibrations, and finally on measurement and test equipment. The responsibilities of the national laboratory were described, including measurement support and calibration services. The laboratory has appropriate primary and secondary standard dosimetry facilities. IRD has successfully participated in major comparisons of air kerma measurements of Co-60 (with EUROMET and BIPM) and absorbed dose to water measurements of Co-60 radiation for radiotherapy (with EUROMET and COOMET). The laboratory also participated in IAEA comparisons of air kerma measurements for SSDL and obtained acceptable results. Other key comparisons in which the laboratory has participated include radionuclide metrology (with CCRI using Ge-68) and neuron metrology (with BIPM CCRI using Am-Be sources). The laboratory provides some services on a routine basis, including calibration of a range of monitors for neutrons and gamma, calibration of personal dosimeters for neutrons and gamma, and calibration of ionization chambers for radiation protection. Challenges facing the laboratory include developing primary standardization, maintaining metrological standards for measurements performed outside the laboratory in the country, developing new standards for new technologies, and knowledge transfer.

The second presentation from Belgium addressed how he is coupling of risk-based thinking with a graded approach can provide for a cleaner QMS for technical service providers (TSP) in occupational radiation protection - clean versus lean. By way of introduction, the presenter explained that accreditation involves accrediting a dosimetry system (detector, dosimeter, reader, and computer), not an analytical method. In personal dosimetry, the processes are less complex and highly automated, but a lot can still go wrong. The focus of this "classic ISO /IEC 17025 accreditation for TSP was reviewed. After 20 years of audits at more than 20 technical service providers (TSPs), the presenter felt that procedures are written for auditors. Manuals and procedures sit on shelves, writing documents are seen as the main goal, quality is the role of the quality department, and it's all about getting signatures.

Learning from occupational radiation protection good practices and using a risk-based, graded approach in the QMS, the focus of the QMS should be on preventing and/or detecting latent and active errors (human, technical, etc.) that impact stakeholders using the results of TSP. Therefore, a QMS is not just a layer of procedures and documents, but it should integrate different barriers – training, software codes, QC, blind/dummy testing, etc. - thus minimizing the risks that develop into events, errors, or problems. Procedures are not the goal in this view, but only one of the tools where the lack of procedures can lead to errors. Thus, we recognize that not all activities/processes carry the same level of risk and therefore do not require the same level of detail in the QMS. In this way, we can implement the strongest controls where it is important and fewer controls where it is not, which helps minimize effort, resistance, and overall cost while improving the quality of results. In addition, it is needed to look at the fit for purpose principle which is also one of the basic principles of ISO /IEC 17025. The maximum expanded uncertainties are in the order of magnitude (coverage factor 2) of 40%, which is close to the 95% confidence interval of 0.67 to 1.5 (factor 1.5) given by the ICRP) Sources of error that contribute < only a few % are less relevant for control. The impact of risks in reporting related to occupational radiation protection can also be investigated. At the investigation level, the cause or effect of the outcome should be investigated. A company should initiate a review of the protection arrangements and address how a particular level above the investigation limit was arrived at. Can 2 mSv be reported as 1 mSv, implying no investigation and vice versa? There is a risk of false positives and false negatives at levels between 50 µSv and 80 µSv. Can a true dose of 150 µSv be reported as 80µSv (false negative), which would cause exposed workers to tend to reduce their preventive measures, or vice versa (false positive)? In all cases, this can lead to distrust of TSP by regulators, exposed workers, radiation protection officers, etc.

It is important to recognize that reader calibration factor (RCF) instability leads to false negatives, while RCF stability leads to false positives, implying that the RCF is not adequately controlled. In terms of the risk management process, some controls may not be necessary. The first example is the control of temperature/humidity in the reader or dosimeter storage room. It is true that the effects of uncontrolled temperature or relative humidity on the reader or detector storage can result in signal loss due to static electricity, condensation, etc. However, type tests show that the effects are only a few to a maximum of 10% at 40°C or 90% relative humidity, and only a few percent under normal laboratory working conditions. Current controls include temperature and relative humidity measurements; there are temperature and relative humidity criteria, calibrated temperature and relative humidity meters, trend control charts, etc. The inherent risk priority number (RPN) of 6 can be assigned on the basis that the impact is not negligible, but the probability is extremely low and detectability is high. The proposed action is no longer an annual calibration (but a simple verification every five years)

Another example is the work instructions for document management. While it is possible for the laboratory technician to use an incorrect version or one that is unfamiliar to him or her, dosimetry systems run largely automated with very little manual intervention during analytical tasks. Laboratories tend to use well-validated software codes. During internal and external audits, document management is examined in detail. With an RPN of 11 (moderate impact, medium likelihood, adequate controls), the action could be to drastically reduce the number of instructions, automate the workflow as much as possible, implement good training tools, use visual work instructions (YouTube-like videos), e.g., for troubleshooting readers, assembly/disassembly techniques for all dosimeter models used. The RPN of 6 does not go up.

There is also an example of inadequately controlled risks such as reader calibration, RCF factor, and reader stability (sensitivity, spikes): The Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation Protection from EC Radiation Protection 160 require two annual calibrations. This can lead to false results (false negative/false positive). Current controls include monthly checks with irradiated dosimeters or an internal source of the reader. Instrument performance is inadequate and is not systematically checked: Photomultiplier tube noise (PMT), reference light sensitivity, dark current. An RPN of 67 is assigned (very high impact, probability quite high, required controls “low"), “and measures may include a daily quality control at the beginning of a dosimeter batch, a quality control dosimeter at the report and testing level, and background checks. The RPN can be as low as 11.

From the analysis of about 100 risks, it can be concluded that even in ISO /IEC 17025 laboratories, some risks are still not acceptable, many are in the ALARA zone, but some are acceptable. Simplifications in the QMS are possible without increasing the risks, e.g., calibration of auxiliary instruments, internal audits, training records, logbooks, personnel evaluation (use of blind tests), etc.: TSP Processes do not involve a high level of manual intervention (no sampling, no extensive preparation), and critical steps in the analysis process are automated with quite good, validated software codes, as we have quite high uncertainties.

There is a need to move away from the paper tiger to QMS that demonstrates fit for purpose. TSPs should move away from a procedure-oriented system to a process-oriented system. The usefulness of internal quality controls, blind testing, inherent quality controls (automated validation by looking at historical data for exposed worker looking for outliers), looking for historical data on ratios of Hp (10)/Hp (3)/Hp (0.07), etc. needs to be improved to demonstrate the effectiveness of TSP 's processes. However, knowledge of useful tools for method verification, internal quality control, and blind testing is still limited. Too much emphasis on paperwork diverts the attention of TSP staff from what is really important. This would lead to a cleaner QMS.

Discussions in the session indicated the continued need for implementation of a regulatory framework for technical service providers, along with harmonization, individual monitoring, and national dose registries supported by proficiency testing and key comparisons. Consistent application of correction factors is needed to improve dose estimation in extremity, eye- lens, and neutron dosimetry, and the specific nature of quality management systems for technical service providers in occupational radiation protection requires the development and implementation of standards.

13 EDUCATION AND TRAINING IN OCCUPATIONAL RADIATION PROTECTION

IRPA presented a keynote address on the IRPA guidance on certification of a radiation protection expert. IRPA is composed of 53 associates societies, 68 countries, and over 18,000 individual members. It has vast resources of practical knowledge and experience in radiation protection, including scientists, operators, regulators, medical practitioners, and advisors, covering multicultural background, large and small societies. The role of IRPA is to promote IRPA as the international voice of the radiation protection profession through engagement with other international organizations and professional bodies. The goal is also to promote excellence in the practice of radiation protection through national and regional Associate Societies (AS) for radiation protection professionals by providing benchmarks of good practices and promoting professional competence and networking. IRPA promotes the application of the highest standards of professional conduct. The third aim is to support education and training (E&T) of RP professionals. To promote E&T internally by organizing discussion forums during IRPA congresses and to promote and support the organization of E&T activities either by IRPA or by its AS.

IRPA’s primary goal is to promote excellence among radiation protection professionals. Therefore, many of IRPA’s AS around the world are actively involved in schemes which assess and certify the competence of individual radiation protection practitioners to perform safety-related work. Given the growing pressure, particularly from regulators, to improve this approach, many other AS are currently considering introducing such schemes currently or in the future. IRPA also cooperates with international and regional organizations involved in E&T in radiation protection.

In the future, IRPA is expected to cooperate with international and regional organizations involved in E&T in radiation protection, such as the IAEA, the European Training and Education in Radiation Protection (EUTERP) foundation platform, and NEA. IRPA assigns top priority on skills, competencies, and knowledge in a number of ways, including education and training and the use of radiation protection codes to maintain competence. The Covid crisis showed an opportunity to better communicate in virtual mode! It is easier for students to follow on screen at home than to travel and to look for fees for the congress.

IRPA also ensures that appropriately qualified radiation protection professionals, radiation protection officers (RPOs), and radiation protection experts (RPEs) will be available in the future by providing a medium for communication and advancement of radiation protection throughout the world. To evaluate its activities, IRPA conducts a survey every four years and helps explore and share concerns about the age profile of current professionals among its membership. The generation that developed the radiation protection principles and methods used today is gradually retiring. Many radiation protection societies and organizations around the world are concerned about the future availability of appropriately qualified radiation protection professionals (RPO and RPE). This was one of the findings of the survey conducted. In 2008, with regard to the recognition of RPE, IRPA proposed to the International Labor Organization (ILO) that the role of RPE be formally registered under the ILO's International Standard Classification of Occupations (ISCO) system. This proposal was agreed to, with the RPE being included in the group of environmental and occupational health and hygiene professionals.

The United Kingdom addressed strengthening radiation protection of workers through education and training: an EUTERP perspective. EUTERP is a foundation established under Dutch law that acts as a focal point for the exchange and dissemination of information and resources and promotes the development of standards and good practice in radiation protection training. To achieve its goals, EUTERP maintains a website, publishes newsletters, and maintains an education and training database. To this end, EUTERP also engages interested parties such as associate membership benefits, national contact points, and liaison partners (ICRP, IRPA, IAEA, HERCA, EAN, EFOMP). The organization also supports education and training through program committees (Education and Training in Radiological Protection (ETRAP), IRPA) and limited participation in social media. EUTERP strives to achieve outcomes as per GSR Part 3 Requirement 26 on information, instruction, and training. The organization also seeks outcomes under BSDD: 2013/59.EURATOM Article 15 on training of exposed workers and information provided to them. The results of a survey conducted by EURTEP in 2007 showed that radiation workers should be suitably trained and qualified, i.e., they should have appropriate skills, information, and knowledge.

Malaysia discussed about country approach to education and training in occupational radiation protection: an experience to be shared. Regulation of applications involving ionizing radiation dates back to 1968 when the Radioactive Substances Act was enacted, followed by the establishment of a regulatory body, the Atomic Energy Licensing Board (AELB) in 1984 through the Atomic Energy Licensing Act No. 304. Regulatory requirements are set out in the Atomic Energy Licensing (Basic safety Radiation Protection) Regulations, 2010, including requirements for the employment of radiation protection officer and qualified experts. In 2005 and 2011, Malaysia invited EDUTA missions, followed by ORPAS missions in 2017. By 2020, the total number of medical applications was 4,921 with 22,700 occupationally exposed workers (OEWs), while for non-medical, the number of licensees was 1,482 with 14,900 OEWs.

There is a national Committee for the certification of radiation protection officers (RPO) training centre. The nuclear education and training infrastructure with stakeholders include regulatory body (regulatory matters), training service providers (conducting training), educational institutes (provide training resources), and certification bodies (for accreditation, syllabus and examinations matters). In addition to these groups, Government, policy makers, industry, non-government organizations, scientists, and the public are important stakeholders in ensuring sustainability. The current state of education and training includes undergraduate, graduate, and postgraduate programs at universities. There are 11 approved training providers and a total of 114 approved training courses for 2022.

In summary, comprehensive and integrated planning and implementation to develop a national strategy on education and training in radiation transport and waste safety (RTWS) should involve all relevant stakeholders in the context of human resource development in Malaysia (industry, educational, institutions, etc.). The current national committee for certification of RPO functions is an important tool and need to be strengthened. The need for a formalized education and training policy/strategy is in line with Malaysia's education and training goals for sustainable societal well-being. The community of nuclear education and training in Malaysia is making great efforts to strengthen its capabilities at the national level, including creating linkages, networks, and sharing information and resources.

Ghana addressed education and training of occupationally exposed workers in Ghana and Africa - Ghana's experience. The uses of ionizing radiation in Africa generally spans several sectors, including healthcare, industry, oil and gas, agriculture. Research and teaching, and nuclear power. Education and training activities in radiation protection are regulated. In Ghana, such activities are regulated by the Nuclear Regulatory Authority (NRA) No. 895 of 2015, which established the NRA as an effective independent regulatory body. This replaced the provisional National Defense Council Law (PNDCL) No. 308 of 1993, which established the Ghana Atomic Energy Commission (GAEC). GAEC is both a research and development institution and a provider of technical services. Currently, the College of Ghana is accredited to provide education in nuclear sciences and radiation protection leading to the award of Master of Philosophy (M.Phil.) and PhD degrees. The School of Nuclear and Allied Sciences (SNAS) is accredited to offer graduate programs in health physics and radiation protection, medical physics, and nuclear engineering. The Radiation Protection Institute (RPI) under GAEC is approved by NRA to provide training for RPOs and radiation protection officers. The training courses include theoretical presentations and practical exercises and last between 3 and 5 days at the client's facilities or at the RPI premises. syllabus and training material requirements are specified in the national policy for education and training in radiation protection, transport, and waste safety, as well as in the training modules for various practices. The policy considers IAEA standardized training modules for various practices based on the 2014 BSS requirements (GSR Part 3). Continuous development of new training modules based on needs assessment and specific competencies of clients is required and usually carried out. The RPI provides training in occupational radiation protection and safety at the national and regional levels for qualified professionals, radiation safety officers, and mine workers. Other participants include radiographers and X-ray technicians, radiologists, physicians, medical physicists, biomedical engineers, nurses, etc. Operators of X-ray and gamma scanners, and front-line officers in emergency planning and response, etc., are also among the trainees.

Postgraduate education and training in occupational radiation protection began in 2006 under collaborative arrangements with SNAS, the University of Ghana, GAEC, and the IAEA. SNAS conducts accredited M.Phil. and PhD in Health Physics & Radiation Protection. SNAS became an IAEA Regional Designated Centre (RDC) for Radiation Protection in 2011 and began offering an IAEA Postgraduate Education Certificate (PGEC) in Radiation Protection and Safety of Radiation Sources in 2011. In 2014, SNAS became IAEA RDC for Medical Physics Academic Education. Under the Norwegian Partnership Program for Global Academic Cooperation (NORPART), academic exchange programs are conducted in medical physics, Radiation Protection and Radiography Education, science, and technology. In the future, basic, intermediate, and advanced courses in radiation protection and the development of specialized modules in the fields of medicine, oil and gas, industry, research, etc. Plans are also underway to develop e-based and online modules for education and training, incorporating artificial intelligence and virtual reality tools. Capacity building of RPI/GAEC will make the organization an efficient and competent TSO in Ghana and Africa.

The overview of the discussions in the session demonstrated the need for ongoing post-graduate education for all professionals exposed to ionizing radiation. All levels of workers, no matter how simple their tasks, should receive customizable training on how to work safely with radiation because the way forward is to develop basic, intermediate, and advanced courses. The role of mentoring the younger generation by ageing radiation protection professionals could be explored. It is also important to provide appropriate information and adequate instruction is given to those who need it. A challenge is to maintain competence, or in some cases even awareness, which may be potentially enough under occasionally exposed occupational staff.

14 SAFETY CULTURE IN OCCUPATIONAL RADIATION PROTECTION

USA presented a keynote paper and addressed US. NRC: Safety Culture in Occupational Radiation Protection. The NRC mission is to license and regulate the Nation’s civilian use of byproducts, radiation sources, and special nuclear materials to ensure adequate protection of public health and safety, promote the common defense and security, and protect the environment. The history of NRC safety culture begins in 1989, when nuclear power plant operators were inattentive and unprofessional in their service, and ends in 2011, when the final Safety Culture Statement (SCPS) was published in the Federal Register. The SCPS sets forth the Commission’s expectation that individuals and organizations engaged in regulated activities create and maintain a positive safety culture commensurate with the importance of their actions to safety and the complexity of their organizations and functions. Nuclear safety culture is defined as the core values and behaviors that result from the collective commitment of leaders and individuals to prioritize safety over competing goals to ensure protection of people and the environment. Nine safety culture safety traits were discussed. In 2013, the NRC developed a common language initiative for safety culture. This initiative includes 10 traits of a healthy safety culture, 40 attributes (performance characteristics) that represent those traits, and numerous examples. The common language for safety culture was finalized in 2014 and published as nuclear regulations, NUREG 2165. The safety culture policy statement education tools are provided by the NRC's safety culture educational resource workbook, which consists of trait talks, case studies, and SCPSs. The NRC has created a trait talk and a licensing or community scenario to understand the 9 traits of safety culture. Experience has shown that certain personal and organizational traits are present in a positive safety culture. A trait, in this case, is a pattern of thinking, feeling, and behaving that emphasizes safety, especially in goal conflict situations. Each trait talk includes a fictional scenario based on another licensee or community. The scenario used in this talk is related to the materials industry.

The NRC implement allegation and enforcement program, which deals with concerns related to NRC requirements and wrongdoing by individuals or organizations licensed by the NRC, applicants for licenses, licensee, contractors or vendors or employees of any of the above. The Allegations Program does not evaluate issues concerning the conduct of NRC employees or NRC contractors. allegation program, NRC reviews and addresses allegations reported to

NRC to include concerns that employees are discouraged from raising nuclear safety concerns (i.e., “chilled”). If a "chilled environment" is identified, the safety culture is addressed through the use and issuance of "chilling effect letters" (CELs). If discrimination or wrongdoing is identified, confirmatory orders (COs) are issued under the Alternative Dispute Resolution (ADR) program.

WNA addressed safety culture practices in the Canadian uranium industry. Uranium operations in northern Saskatchewan (Cameco operations) include the Key Lake Mill, MacArhur River Mine, Cigar Lake Mine, and Rabbit Lake Mine/Mill. The current number of employees is 1000, of which 700 contractors whom about 50% are indigenous. In Ontario, Cameco has over 700 employees. The safety culture practices in the Canadian uranium industry focus on Cameco’s experience and practices. Step change in safety culture occurred in 2004 when the Canadian Nuclear Safety Commission (CNSC) hosted a workshop indicating its intention to formally incorporate the issue into the regulatory system. Cameco worked with an external consultant to develop a safety culture framework. Consultations were then held with senior operations and safety management personnel to articulate the key attributes of a good safety culture. The safety culture attributes were organized around 5 overarching principles, largely aligned with those of the IAEA and CNSC.

The strong safety culture has been incorporated into management documentation and implemented at all levels of the company as described in safety, health, environment, and quality (SHEQ) policy (consisting of corporate and site level programs - risk assessment, safety standards, corrective actions and audit procedures). In the policy, communication is handled by senior management, and all meetings begin with a safety moment. Cameco conducted its first formal safety culture assessment in 2005 and has continued since. The assessment is conducted approximately every 5 years at each site, typically 1-2 times per year. The assessment process is led by senior management, who assemble a team from across the company. Two major data collection methods for assessing safety culture were described and discussed. These include a written survey of all employees on a scale of 1 to 7 and interviews conducted by the assessment team a few weeks after the survey. The results show that the percentage of agreement (score $\geq$ 5) was 75% for the survey and 74% for the interview. Information is shared freely between the working groups. Experience has shown that most questions are scored similarly in the surveys and interviews – but not always. In 2018, CNSC published a set of rules defining safety culture to include security culture. Cameco had not previously considered security culture in safety assessments, and therefore security-related questions were included in the framework. The Institute of Nuclear Power Operations (INPO) safety culture framework is a useful analysis and presentation approach. Cameco’s safety culture questions were applied to the INPO framework. The results of the data collection are shared with site management with the details and key themes that were observed. This rarely leads to major surprises for site leadership and helps prioritize and reinforce existing improvement plans. Finally, the site response results are presented to senior management. Having a strong safety culture is widely accepted as being a key to Cameco’s success.

The contribution of FORO’s safety culture projects to enhance occupational radiation protection in Latin America was discussed by Cuba on its behalf. FORO was established in 1997 and consists of 10 regulatory bodies. FORO program includes radiation protection of workers, human and organization aspects, and has been undertaking projects on safety culture.

The first projects were to establish guidelines on safety culture in organization, facilities and activities involved in the use of radiation sources in 2012-2015. The scope of this project was on radiation protection and safety culture plus security culture, activities related to medical, industrial, research uses of radiation sources, radioactive waste management and transportation of radioactive material, and on general approaches. The guidelines approach includes among others the use of ten basic elements of safety culture (traits), safety culture assessment defined at 4 levels, and 62 proposed safety culture indicators. After project completion dissemination of FORO guideline to enhance safety culture awareness was held from 2015 to 2022. The awareness program consists of 2 regional workshops, 3 national courses, 1 national seminar, and through REPROLAM network. In addition to awareness program, practical use of training material was developed, publications (IAEA TECDOC and FORO website), and practical use of safety culture assessment were other post- project actions. The second project was pilot implementation of safety culture assessment methodology from FORO guidelines to organizations with industrial radiography from 2017 and is still going on. The highlights of project output were presented including a comprehensive interim projects report. FORO guidelines on safety culture is a dedicated document to support organizations using radiation sources in understanding and developing safety culture to enhance occupational radiation protection of workers. Building capacities are needed in developing countries to increase safety culture awareness among regulators, facility managers, and workers for training of safety culture evaluators. Regional schools on radiological safety culture could be one way forward to this purpose.

South Africa addressed a topic on safety culture in occupational radiation protection: the Tygerberg hospital experience. The hospital has 100,000 admissions annually over 30,000 operations, 67 wards, 29 theatres and approximately 4,400 staff and about 400 radiation workers. About 17% of South Africa population has access to private healthcare, but private sector accounts for about half of all country's healthcare expenditure and employs 70% of healthcare specialists. The situation is likely to be attributed to economic inequality in the country. Legal and Regulatory framework as well as professional recognition in medical applications of ionizing radiation were described. Among the regulatory requirements is the need for occupationally exposed workers to be radiation monitored. Examining pre-Covid -19- year situation, the hospital possessed over 4707 individual dose records in 19 hospital departments. About 95% of records shows doses below equipment detection limit i.e., 0 mSv, with the highest dose in a single wearing period being 0.91 in nuclear medicine considering top 10 data of 10 different people. The highest dose in cardiology radiology was 0.76 which was the only profession in top 10. The highest annual dose in year for 13 wearing period was 5.18 mSv from nuclear medicine with cardiology being the only work category in top 10 and recorded 2.43 mSv. For finger rings, the top 10 data in single wearing period ranged from 9.51 to 18.14 while top 10 for the year ranged from 14-82.4 mSv, and no eye lens data. As it has been seen all exposures were well below any action levels and no dose was above 4 mSv in any wearing period. The question is whether the performance is good or a complacency. Based on previous experience the highest dose was expected from Cath Labs or other areas where fluoroscopic guidance is used frequently but this is not the case. This could be related to radiation safety culture which is much more than occupational radiation protection. To improve the situation, training course on safety culture were conducted to occupationally exposed workers. Training course was based on 10 radiation safety culture trait talks.

Morocco discussed strategic approach to develop a national program for Nuclear Safety and Security (NSS) culture and leadership: A case of AMSSNuR/Morocco. The Law 142-12 on nuclear safety and security was promulgated in 2014 and established *L'Agence Marocaine de Sûreté et de Sécurité Nucléaires et Radiologiques* (AMSSNuR) as a regulatory body. The constitution of applications involving ionizing is 75% (medical uses), 15% (industrial uses), 5% (research reactor and irradiators), and 5% (others). Nuclear Power Plants will be considered beyond 2035. The strategy documents the national commitment at the level of the head of Government, internal organization commitment (AMSSNuR's Director General, steering committee formation, and roadmap programme). The strategy adopts IAEA's references regarding responsibility for safety, role of Government and leadership and management for safety. Self-assessment on NSS was organized and involved questionnaire by working group in consultation with IAEA and administration of questionnaire during the national workshop on NSS in 2019. The obtained results were disseminated during the national workshop on leadership in nuclear safety and security in 2021. Apart from major achievements of AMSSNuR, the main challenge is integration of all leadership in model components of NSS. There is good progress in implementing AMSSNuR's vision and strategy to sustain nuclear safety and security culture and leadership at the national level and regionally. The progress contributes to regional and international networks. Such networks include Forum of Nuclear Regulatory Bodies in Africa (FNRBA), Global Nuclear Safety and Security Network (GNSSN), International Network for Education and Training for Emergency Preparedness and Response (iNET EPR), and Arab Network of Nuclear Regulators (ANNuR).

A review of the discussions in the session on radiation safety in occupational radiation protection indicates that core values and behaviors resulting from the collective commitment of leaders and individuals are needed to prioritize safety over competing goals. A systematic approach is needed, especially for operators with regulatory guidance.

15 MAIN FINDINGS OF THE CONFERENCE

At the beginning of the conference, attention was drawn to three main questions.

- What are the technical and regulatory advances, challenges, and opportunities since the last conference on this topic in 2014?
- What is the global situation of worker radiation protection in general and in particular?
- What is the foreseeable direction for the future that requires prioritizing our actions?

At the end of the conference, the contributions of the participants in the form of presentations and discussions during the conference led to the following main results. The standards for radiation protection developed at the international level are now mature. The framework for controlling, monitoring, and recording occupational exposures is generally satisfactory. This can be seen in review missions such as the IAEA's Occupational Radiation Protection Appraisal Service (ORPAS). As emphasized at the Second International Conference on Occupational Radiation Protection, changes to standards should be made only when necessary to reflect improved scientific understanding of the effects of ionizing radiation or to fill gaps, improve clarity, facilitate application, or ensure that the required level of protection is achieved. The ICRU-95 report on new operational quantities reflects this improved scientific understanding of ionizing radiation. The recent ICRP initiative to review and revise the radiation protection system, which includes updating the 2007 General Recommendations in ICRP Publication 103, will be important to the ORP community. In addition, unjustified changes may have unexpected and negative side effects and undermine confidence in the radiation protection system. Continued attention to the development of the ethical basis of radiation protection will contribute to more consistent application, understanding, and communication.

Exposure to natural radiation is an inescapable, normal feature of life; however, the international approach to managing radiation exposures in industrial activities and processes involving NORM is currently inconsistent and unnecessarily complex. This is one of the key findings of the IAEA-organized International Conference on Radiation Safety 2020, (https://www.iaea.org/events/international-conference-on-radiation-safety-2020), where it became clear that the concepts of exemption and clearance are part of the graded approach that plays an indirect but crucial role in worker protection because of the approach of GSR Part 3. It was noted that the application of the graded approach needs to be strengthened through optimization processes, which is now attracting greater interest due to the introduction of innovative technologies.

In nuclear power, the industry is benefiting from artificial intelligence in areas such as automation, design optimization, data analysis, prediction and forecasting, and insight extraction. Ongoing efforts are focused on transferring artificial intelligence technologies from pilot studies to broader applications. With respect to occupational radiation protection, artificial intelligence applications and their integration into control and monitoring processes, such as individual dosimetry for external exposure, are expected to enable faster, more flexible, and more efficient processes and have the potential for profound technological change in the field. Artificial intelligence enables the mimicking of human cognition in the analysis, interpretation, and understanding of complicated work processes, including radiation exposure.

16 DRAFT GENEVA CALL FOR ACTION

Based on the second conference in Vienna in 2014, nine action items were identified and each of them has been successfully accomplished during the following years. Similarly, the 2022 Geneva conference identified some desirable actions to enhance protection of workers, including:

1. Implementing the existing international safety standards and the ILO Radiation Protection Convention (No.115) to enhance radiation protection of workers and supporting Member States with less developed programmes for occupational radiation protection in the practical application of the international safety standards.
2. Assisting Member States in the optimization of protection and safety and the use of a holistic approach for worker protection with the consideration of radiological and non-radiological hazards.
3. Applying the graded approach of the GSR Part 3 in the protection of workers against exposures due to elevated levels of natural sources of radiation, such as radon in workplaces, civil aviation, mining, and raw materials processing industries.
4. Developing and implementing international safety guides for activities with challenges on occupational radiation protection.
5. Continuing to promote the exchange of operating experiences and the application of innovative technologies in occupational radiation protection through different approaches including networking.
6. Strengthening capacity building on monitoring and assessment of occupational exposure and promoting the establishment of a national dose registry.
7. Enhancing training and education in occupational radiation protection to provide Radiation Protection Officers and occupationally exposed workers with necessary knowledge and skills, including periodic refresher training.
8. Improving commitment to safety culture at management levels and promoting safety culture among workers through outreach and education.
9. Supporting the development of young professionals in radiation protection through information, communication, networking, training, education, research, hands-on experience, and participation in technical meetings and conferences.

ANNEX 1 A SUMMARY OF CONCLUSIONS FROM SESSIONS AND ROUND TABLES OF THE CONFERENCE

Peter Hofvander, Programme Committee Chair, Sweden

Thank you, Mrs Chair.

It's a privilege for me to start this Closing Session by trying to summarize a little bit about the outcome or output from the sessions that we have had during this week. And before I go through all of the sessions, I just want to show what this organization has done during this year in preparation. This conference is cosponsored by a lot of organizations, as you can see on the slide. And we have also had a Programme Committee that has started about a year ago to prepare all these sessions with the speakers and so on, and not least the Secretariat from the IAEA and ILO to make this conference good.

Before I start, I also want to thank all the contributors that have provided input for the conference, like the all the Chairs, also the Co-chairs and the Rapporteurs, and all the presenters during the conference. Without them, without you, it would not have been possible to make this presentation today.

Having said that, let's talk a little bit about overview of the of the participation. We have had over, to my knowledge, we see 700 participants, and in real life here in-person 280, and a lot of participants in virtual – 430. And it's covered 105 Member States and 17 International Organizations.

As you know, we have had a lot of thematic sessions, I will go through them one by one, and also round tables, including the Young Professions Round Table yesterday evening. So, you can see also on the map, from where in the world we have contributor papers and speakers, and we try, the Agency tries also to have regionally spread all the contributions. That's a very important issue when we prepared for a conference.

So, let's continue. We had an opening session this Monday, and also a Briefing Session, where we had a presentation from the IAEA, the ILO, IOE, ITUC, FOPH, NSI and so on, that gave an overview of the past and present perspectives in the occupational radiation protection.

They were highlights on progress in 2014 Vienna conference that was eight years ago, and the implementation of actions developed of guidance materials, regulations and organization requirements, provisions, safe and healthy working places. We also had the challenges in Fukushima, increased movement of itinerary workers, one issue that was highlighted. And also we had a Keynote speech in the end of this session that kindly also suggested some development on the diplomatic conference and perhaps a code of conduct in occupation protection.

In the Briefing Session, we had further contributions from the IAEA, ILO, from the European Commission, the OECD Nuclear Energy Agency, UNSCEAR, WHO, ICRP and IRPA. They try to cover the activities on occupation protection, including the main challenges that we can see in the future. And what was noted was that there is a good progress over the last 20 years of the actions. There's a need for scientific data to make risk-informed decisions, that's an essential issue. Those assessment for occupation exposed workers was also mentioned and also to continue to engage all parties in the open communication with stakeholders. The key focus areas include but not limited to the existing exposure situations, for example, radon in workplaces, industrial process involving norm and cosmic rays, migration protection.

Session 1, that was the review of the standards and recommendations in occupation protection at the international, regional and national levels, and also here was the progress of the past 20 years and the existing challenges of what was requested. We heard that the regulatory framework was important to improve the control over occupation exposure through implementation enforcement, including update regulations, regulatory guides, and license conditions.

Of course, adopting the GSR Part 3, the safety guides and international best practices are essential. We also heard the use of realistic human phantoms provides for more accurate occupational radiation dose assessment by the ICRU report 95, and we also heard that allowance for licensees and regulators to supply those constraints for workers allows for the optimization of protection.

More in the Session 1, of course, radiation protection training is also important, it is crucial to improve the safety culture. National dose registers developing national radiation safety training strategy, national qualifications recognition criteria for radiation protection officers are always for better implementation of the requirements. There's a need to adopt consistent terminology that was also discussed this first day, and also some suggestions were raised to reduce the number of protection quantities.

Session 2 was on monitoring dose assessment of occupation radiation exposure. And here we had a talk from ICRU on new operation quantities, more coherent with the current protection quantities. There will be some changes in practice, and there will be challenges to redesign the characterization of personal dosimeters, especially for gamma meter radiation at low energies. We also heard that solid-state dosimetry remains relevant for individual monitoring. New technologies are coming and will reduce the need for passive dosimeters in the future, for instance, computational dosimetry.

There was also a talk about neutron dosimetry and also artificial intelligence to analyze neutron dosimeter based on solid state nuclear track detectors. A presentation on internal dosimetry made it clear that this is a complicated calculation, but that ICRP also has been working since many years to provide those conversion coefficients to simplify all these assessments. Eye lens dosimetry with online dosimetry simulation and application for new techniques was also part of this session.

Session 3 was on radiation effects, health risks of occupational exposure and workers' health surveillance. UNSCEAR had the presentation on the 2012 report that was published in 2015 and that's about attributing health effects to ionizing radiation and inferring risks and it contains, for instance, risk assessment, low doses and advice that can be applied to evaluate radiation related detrimental health risks.

We heard a presentation on epidemiological studies of occupationally exposed cohorts indicates broad alignment with the risk-to-dose responses from Hiroshima and Nagasaki A-bomb survivors. We heard the talk about the variation of the risk of lung cancer mortality with radon dose confirmed by the publication from the PUMA studies combined with Asian minor cohort.

From ILO, it was also highlighted that the convention 115 is important, recommendation on 114 also concerning the protection of workers against ionizing radiation, and that there is also policies on workers' health surveillance that we should apply number 161 recommendation 171.

WHO had a key message in their talk on radiation protection of health workers is essential and should be based on justification, optimization of protection, and application of dose limits. Regular monitoring is crucial for limiting unwanted exposures.

Round Table 1, health risk management with Member States' approaches: Here we have international organizations, ILO and WHO promote the need to improve the possibility to access the occupation, health and safety services, including workers' health surveillance, involvement of workers' trade unions, and collaboration with more fundamental points to achieve this goal. Experience of multinational companies having thousands of workers employed worldwide integrated a single health and safety management system showed that the large majority of occupational injuries could be all preventable. And finally, in the medical facilities, accidents are possible with consequences of high-level radiation exposure and possibly critical injuries. Corrective actions are needed with the disciplinary approach.

Then we went to the session number 4 that was on occupational exposure levels and dose registries. You heard me present the UNSCEAR's latest report on occupational exposure by ionizing radiation. The UNSCEAR 2020/21 report that provides an update of global occupational exposure up to 2014. The last report was produced in 2018, provided data until 2002. Exposures to natural sources dominate the average effective dose for workers at 1.9 mSv versus the 0.5 mSv for human-made sources. More could be read about in the report.

More in the Session 4, well-established German national dose registries provided an overview of German exposures with the focus on pandemic impact on civil aviation. The review of China's national dose registry data shows statistically significant degrees in doses for workers. 17 nations in Latin American Caribbean have implemented variations of the same, and the natural dose register systems developed in Cuba, and Ghana has introduced a dose management system for users to manage worker dose because and or in the process of implementing national dose registries.

In Session 5, occupational radiation protection in industrial, research and education facilities, occupational radiation protection is relatively mature, systematic approach involving RPOs, training and qualification following the IAEA Safety Standards. However, still high doses in some cases, occasional accidents, lack of training for some radiographers, improvements in harmonization of training and communication are needed. The crucial role of the ISEMIR information system with the ISEMIR for industrial radiography. Main challenge is to get involvement from the NDT industry.

Session 6 – Occupational radiation protection in nuclear power plants and nuclear fuel cycle facilities. ISOE is an important database to improve management of the occupational exposure, an opportunity to learn, network and benchmark. New challenges will be lifetime extension in existing plants and decommissioning.

Important to begin monitoring prior to construction, use of simulation tools to calculate the impact on normal and accidental conditions, important to include existing standards in evaluation phase was heard from Poland.

Strong safety culture, including leadership and environment, radiation, etc., and safety reports are considered helpful to assist newcomers in radiation, also for a graded approach was another message during this session. Huge impact not only on radiation protection issues, but also environment, the amount of waste and need for extensive monitoring programme.

Further on Session 6, the importance to collaborate on the international level. From a regulatory perspective, review missions against international standards are important and have generally been in agreement. Information to the international community is crucial, maintain attention on radiation protection, utilize science and technology and improving radiation protection, share knowledge and experience, be ready to deal with new situations, pandemic, war, etc.

Session 7 - ORP in workplaces involving exposure to NORM, radon, and cosmic rays. Here is a broad, realistic view of radiation protection. Related to NORM in the United States were presented considering cosmic rays in aircrew and astronaut exposures. Aspects related to drinking water and radon were also considered.

A concise summary of the NORM X Symposium showed that new era for the use of residues in the circular economy in order to balance the radiological features versus economic uses. A presentation that demonstrated the systematic validation of the software used to estimate the dose to aircrew, showing that these are among those who receive the most significant effective dose. The comprehensive presentation of radon monitoring in some workplaces, showing the structure, practical issues identified during the mapping.

Regarding exposure to natural sources of industry involving NORM, exposure to radon in workplaces, and cosmic radiation of flight and space crews. Following summarized the Commission in the common issues: economic importance of industries, doses are generally, but not always, moderate, potentially high cost of regulation in relation to reduction in exposure.

The graded approach optimizes the use of regulatory and operators resources. Exemption, notification, registration or licensing are in place with national approaches. Regulation and strategy for regulations required when exposed to both certain levels and to determine the optimum regulatory approach considered the particular types of operation, a prior radiological evaluation, if possible, consideration of the costs of regulation in relation to the benefits, consideration of arrangement on control, monitor record of occupation exposure.

We had the round table on radon exposure. Radon dominates exposures of natural sources of most workplaces. Radon should be assessed in all workplaces. The assessment should follow graded approach to determine if control and regular monitor are needed. And if the round table discussion ended with the statement that radon can be controlled, elevated radon can be reduced, radon can only be a problem if it's ignored.

I move on to number 8 that was on the medical uses, occupational radiation protection in medicine. Evidence is of reliable systems of RP in place. Modalities such as interventional radiology and molecular imaging therapy can result in high doses. Here, optimization of protection is essential.

Reduction in limit for dose to lens of the eye has been a key focus for research. Appropriate use of protective equipment essential for optimal protection, use of available safety standards, and other resources can support good systems of radiation protection.

Also, there was a round table in medicine – the way forward. By far, the greatest potential risk for workers in the interventional fluoroscopy procedures. While tissue reaction cannot be ruled out for patient, workers are at the risk of stochastic effects. Many good practices can and should be taught to the workers.

We had also, a little bit further down, communication is a two-way process. All stakeholders need to be involved. Feedback and knowledge sharing should be formally organized. When multiple documents are to be worn, it's important sure that this is the case. Your dose in real time is a good way to sensitize workers.

Number 9 – optimization of occupational radiation protection, that was yesterday. Optimization of radiation protection is to reach a reasonable level of risk, need to take into account the specificities of exposure situations that will impact the stakeholders to be involved and the decision-making process. In the future, new technologies should be used to support optimization / ALARA, notably at the planning stage.

The round table on optimization of radiation protection: All the regional networks agreed on the importance to establish context between networks to exchange experiences that could be fruitful in the future improvement of the existing networks. There was a general agreement that to act in, the network has to identify what actions are most needed in their region and work for handing these.

Technical service providers, number 10: There is a continued need for implementation of a regulatory framework for technical service providers along with harmonization, individual monitoring and the national dose registers was identified, assisted by proficiency testing and key comparisons.

Consistent application of correction factors is required to improve the dose assessment in extremity, eye-lens, and neutron dosimetry and the specific nature of quality management systems for technical service providers in occupational radiation protection calls for development and implementation of standards.

Education and training: Need for ongoing post-graduate education to all professional workers who are exposed to ionizing radiation. All levels of workers, no matter how basic the tasks they have, should receive an adjustable piece of education on how to work with radiation in a safe way, for the way forward is to develop basic, intermediate, and advanced courses.

Also, it was mentioned in the discussion the role of mentoring of the younger generation by ageing radiation protection professionals could be explored. It is important, too, that appropriate information and adequate instruction is given to those who need it. One challenge is to maintain competence or in some cases even awareness, which may be potentially enough under occasionally occupational exposed staff.

And then yesterday evening we had a Young Professional Round Table – Being a young radiation protection professional. And some bullets from this is that the young professions are very open to and at the forefront of new techniques / innovations such as 3D models, virtual reality, robotics, ORPNET migration. It may be a way to capture young professionals and revitalize the radiation protection field.

Young professionals also face specific challenges: the women representation, lack of mentorship programme, difficulties in transboundary movement, balance between visibility versus inclusion in organizations and conferences, etc. These are hot topics that young national network is approaching.

And today, we have already heard safety culture in occupational radiation protection. Core values and behaviors resulting from collective commitment by leaders and individuals to emphasize safety over competing goals. A systematic approach is needed, particularly for operators with regulatory guidance.

Educational and training and the involvement of stakeholders are essential input to fostering a culture of safety at the individual or organization levels. More experience on safety culture measurements is needed to establish baseline levels and subsequent monitoring. Diversity and difficulties of work environment and organization pose challenges which need a holistic approach. Test it with your own methodology. Regional initiatives to support harmonization and experience exchange.

And finally, we had a round table just before this session, on regional challenges in implementing occupational radiation protection. Regional dynamics are different as well known and synergies are needed with regional characteristics.

In Europe, major system RP with solid regulatory framework, we have occupational safety is at high level, RP as well as others. The system is in some part found to be very complex. Application of the system by non-experts, operators and so on or authorities. Often minimization instead of optimization. Comparison of radiation to other risks and comparison of the risks of radiation with the benefits was discussed.

In Asia and the Pacific, we had the limitation of the TSPs, the technical service providers, dose assessment capabilities, establishments and the maintenance and national registers, difficulties and integration with the occupation health services.

In Africa, we had challenges in lack of policies and regulations, monitoring of workers, occupationally exposed to radiation remains a top priority, designation and training of RPOs, establishment of national dose registers and priority for ORP in NROM industrial processes.

Finally, in Latin America, there's an excellent indicator and many completed the IAEA review missions in the region, highest rate of ORPAS. Robust regulatory systems are needed. Focus on training and education in occupational radiation protection, more efforts to improve safety culture, retraining of health care professionals in radiation protection, and there's a use of an advisory council specific to Argentina.

This was very brief and quick and sorry for speaking so fast the summary on this, some outputs of the sessions here at the conference. Thank you very much for listening.

ANNEX 2 CONCLUSIONS OF THE CONFERENCE

A. Lévy, President of the Conference, Switzerland

Excellencies, distinguished delegates, ladies and gentlemen.

Thank you for joining us in this important conference devoted to the enhancement of occupational radiation protection including a review of the twenty years of progress since the very first conference organized in 2002 and developing the way forward after taking into account the call for action from the 2014 conference.

This third International Conference on Occupational Radiation Protection was hosted by the Government of Switzerland, organized by the IAEA, and cosponsored by the ILO in cooperation with other international organisations in Geneva from 5 to 9 September 2022.

This conference assembled over 700 participants, including 280 in-person participants in Geneva, from 105 Member States and 17 international organizations. Subject matter experts in radiation protection and associated specialties from around the world reviewed the status of occupational radiation protection with the objective of enhancing protection of workers by exchanging information and experience and reviewing the global situation on radiation protection of workers by taking into account the technical and regulatory advances, challenges and opportunities since the 2014 conference.

We have come together, shared our insights and challenges, and exchanged information and experience. We have reviewed developments, advances, challenges, and opportunities. Now we are formulating conclusions and recommendations.

If I may echo the talks of the very first day, the IAEA has statutory responsibility to establish or adopt safety standards for the protection of health and the minimization of danger to life and property, including such standards for occupational radiation protection, and also to provide for the application of those standards. The Agency has been establishing such standards, including the Radiation Protection and the Safety of Radiation Sources: International Basic Safety Standards, GSR Part 3, for almost 65 years and has taken stock of the worldwide situation in regard to occupational exposure on the basis of an open and transparent process for gathering, integrating and sharing the knowledge and experience gained from the use of technologies and from the application of the Safety Standards themselves.

With regard to the co-sponsor organisation, the ILO has overall responsibility for occupational safety and health, promotion of a holistic approach for worker protection and application of the Convention 115. This convention has been ratified by, and has thus become legally binding on, 50 countries. The ILO is also a co-sponsor of all occupational radiation protection related Safety Standards, including GSR Part 3 and General Safety Guide on Occupational Radiation Protection (GSG-7).

The IAEA, and ILO in cooperation with the sponsoring organizations, professional societies, employers, and employees work together to ensure protection of workers from ionizing radiation.

The message in the opening speech by IAEA Director General Grossi and further explored throughout this conference, was that countries and multilateral organizations are working together to enhance protection of workers who work with ionizing radiation in order to keep this critical segment of our labour force safe.

Ladies and Gentlemen,

If I may further repeat the key messages, occupational radiation protection needs personalized, highly efficient, and reliable methods and approaches. Over the past two decades, we have the clear evidence that Member States are largely harmonized, but still need tailored approaches for the protection of this critical group of workers in a wider industry than before.

Many delegates have commented that a lot of good work has been done in the area of occupational radiation protection since the 2014 Conference, and that the presentations demonstrated good practical activities and experience. The change in focus from just the high-level professionals to the broader workforce requirements, especially in considering the needs of optimized approaches, is to be welcomed.

It is pleasing to have seen so many examples of IAEA guidance being implemented by Member States across all of the occupational exposure related requirements of GSR Part 3 and recommendations of GSG-7 in line with the 2014 Call for Action. It is even more pleasing to see how the Member States have adapted this guidance to meet their own national needs including activities in workforce planning for optimization for different exposure situations, increased capacities for monitoring, assessment, training and education, mentality change for safety culture.

As a result of local economic, social, and political conditions, gaps and challenges remain where the overall picture of radiation protection is not clear or compelling. This conference has observed that we possess the strength to close these gaps and overcome these challenges in order to enhance protection of workers so that a high level of protection will continue long into the future.

CONFERENCE FINDINGS

At the beginning of the conference, we focused our collective attention on three essential questions:

- What are the technical and regulatory advances, challenges and opportunities since the last conference on the topic organized in 2014?
- In general, and in specific, what is the global situation on radiation protection of workers?
- What is the foreseen direction in the future which requires the prioritization of our actions?

Throughout the conference, I have heard a variety of answers to these questions. I appreciate your attention to these questions as we, altogether, have worked to close the gaps and resolve the challenges in occupational radiation protection. Your contributions have prompted ideas and recommendations on how we can and should enhance protection of workers by building on the momentum from this week's conference.

The Standards for radiation protection developed at the international level are mature and generally satisfactory frameworks for the control, monitor and record of occupational exposures. This can be observed in review missions such as the Occupational Radiation Protection Appraisal Service (ORPAS) provided by the IAEA. As highlighted during the second international conference on ORP, changes to the standards should only be made where necessary to reflect enhanced scientific understanding of the effects of ionizing radiation exposure or to fill gaps, improve clarity, facilitate application, or ensure the necessary level of protection is met. I believe that the ICRU-95 report on the new operational quantities reflects this enhanced scientific understanding of ionizing radiation. Additionally, ICRP's recently launched initiative to review and revise of the System of Radiological Protection that will update the 2007 General Recommendations in ICRP Publication 103, will be very relevant to the ORP community. Unjustified changes can have unexpected and negative side effects and can undermine confidence in the radiation protection system. Continued attention to the development of the ethical basis for radiation protection will assist in its more consistent application, improved understanding, and enhanced communication.

Exposure to natural radiation is an inescapable, normal feature of life; however, the international approach to managing radiation exposures in industrial operations and processes involving NORM is currently inconsistent and unnecessarily complex. This is one of the major findings of the 2020 International Conference on Radiation Safety organized by the IAEA. This conference has made it clear that the concepts of exemption and clearance are part of the graded approach which plays an indirect yet crucial role for worker protection due to the approach of GSR Part 3.

We are all aware that there is a definite need to strengthen the application of the graded approach through optimization processes which is now garnering more interest through the implementation of innovative technologies. In nuclear power, the industry benefits from artificial intelligence in areas such as automation, design optimization, data analytics, prediction and prognostics, and insights extraction. Ongoing efforts focus on the transfer of artificial intelligence technologies from pilot studies to wider applications. With regards to occupational radiation protection, artificial intelligence applications and their integration into control and monitoring processes, such as individual dosimetry for external exposure, are expected to yield faster, more flexible and more efficient processes with the potential for a deep technological transformation in the field. As such, artificial intelligence enables the emulation of human cognition in the analysis, interpretation, and comprehension of complicated work processes including radiation exposure.

And now, we present the **DRAFT 2022 CALL FOR ACTION**.

Based on the second conference in Vienna in 2014, nine action items were identified and each of them has been successfully accomplished during the following years. Similarly, the 2022

Geneva conference identified a number of desirable actions to enhance protection of workers, including:

1. Implementing the existing international safety standards and the ILO Radiation Protection Convention (No.115) to enhance radiation protection of workers and supporting Member States with less developed programmes for occupational radiation protection in the practical application of the international safety standards.
2. Assisting Member States in the optimization of protection and safety and the use of a holistic approach for worker protection with the consideration of radiological and non-radiological hazards.
3. Applying the graded approach of the GSR Part 3 in the protection of workers against exposures due to elevated levels of natural sources of radiation, such as radon in workplaces, civil aviation, mining and raw materials processing industries.
4. Developing and implementing international safety guides for activities with challenges on occupational radiation protection.
5. Continuing to promote the exchange of operating experiences and the application of innovative technologies in occupational radiation protection through different approaches including networking.
6. Strengthening capacity building on monitoring and assessment of occupational exposure and promoting the establishment of a national dose registry.
7. Enhancing training and education in occupational radiation protection to provide Radiation Protection Officers and occupationally exposed workers with necessary knowledge and skills, including periodic refresher training.
8. Improving commitment to safety culture at management levels and promoting safety culture among workers through outreach and education.
9. Supporting the development of young professionals in the area of radiation protection through information, communication, networking, training, education, research, hands-on experience, and participation in technical meetings and conferences.

It has been 20 years since the First International Conference on Occupational Radiation Protection. The experience gained after two decades has been valuable and confirmed the successful application of the safety framework for protecting workers from ionizing radiation. This is a success story for worker protection.

In closing, I would like to thank each of you for your support in widening Member States' capacities to use state of art technologies associated with flaring management, control, and monitoring of the occupationally exposed workers worldwide now and in future generations.

Ladies and Gentlemen, you have had a long week and have participated actively, and I am sure you are all looking forward to getting back to your respective homes, so I thank you once again for your participation and wish you all a safe journey home.

Thank you.