Abstracts

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Live Oral Presentations

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Keynote Speaker

Atomic Bombing, Suffering, and Science

Ohtsura NIWA (Kyoto University (Emeritus Professor))*

Abstract–The atomic bombings changed the world completely. When asked in a television interview about the first nuclear test detonation on July 16, 1945, Robert Oppenheimer replied, “We knew the world would not be the same…Now, I am become Death, the destroyer of worlds.” Three weeks later, this pronouncement became a reality for the people of Hiroshima and Nagasaki, with the bombings of the two cities resulting in the deaths of more than 200,000 people as well as in the destruction of the daily lives of those who survived the massacre. The U.S. government understood the scientific value of studying the survivors and their children to learn about the health effects of atomic radiations and asked the U.S. National Academy of Sciences (NAS) to establish the Atomic Bomb Casualty Commission (ABCC) in Hiroshima and Nagasaki in 1947 and 1948, respectively.

At first, the survivor victims were happy to have access to ABCC, since they believed the organization would provide them treatment for sickness caused by the bombings. Soon, however, they learned that ABCC’s aim was merely to conduct pure science to investigate the effects of A-bomb radiation on their health. In fact, A-bomb survivors and their children were sometimes forcibly taken to the institute for “health examinations,” during which their blood and even bone marrow were collected for reasons never explained to them. Other studies designed to investigate the effects of radiation on sexual maturation involved the taking of photographs of nude adolescent children, to their great humiliation. To make things worse, all these studies were done without their consent. The cruel examinations gave the impression to survivors and community members of the two cities that the United States was using the survivors as Guinea pigs simply to record the detriments caused by the bombings. In 1975, ABCC was reorganized into the Radiation Effects Research Foundation (RERF) under Japanese civil law and operated binationally by the governments of Japan and the United States. At that time, RERF inherited all of ABCC’s research. Unfortunately, however, the institute also inherited the hostility of the local communities. The negative image remaining from the ABCC years made it difficult for RERF to conduct research, since science should never make study participants and their communities unhappy. Even under such circumstances, RERF started reaping the benefits of its research in the 1980s. With the use of newly developed parametric model-based analyses of epidemiological and clinical study data, RERF became the source of observational data of radiation health effects for creating the global radiation protection system (currently based on ICRP 2007).

It is now the 21st century, and science is seeking to understand the mechanisms behind past observational findings. At the same time, this century is a time for consideration of the Ethical, Legal, and Social Issues (ELSI) when research employs human participants and samples. To elucidate mechanisms, it is essential to analyze biosamples and, for this, it is necessary to receive the informed consent of donors. With that, RERF is forced to confront the past negative image of ABCC. RERF somehow also has to engage with the survivors and their children not simply as study subjects but as study collaborators to enable them to share the pride in and importance of RERF’s research. For that to be accomplished, the distance between RERF and the A-bomb survivor participants and their children must be narrowed.

RERF has been striving for the past eight years or so to close that distance between the research institute and our study subjects as well as community members. In today’s talk, I will describe the bombings and the resulting devastation. Thereafter, I will touch upon the suffering of the survivors and their children. Finally, I will explain the past efforts of RERF to improve its relations with the survivors, their children, and the local communities. After all, any professional in the field of radiation research must never forget that the system used for radiation protection around the world is based on the tremendous suffering of the people who survived the bombings in 1945.

Keynote Speaker

Clinical Potential and Prospects for Carbon Ion Radiotherapy from Physical and Biological Properties

Hirohiko TSUJII (QST hospital, National Institute for Quantum Science and Technology)*

Abstract–The principle of radiation therapy is to concentrate radiation on the tumor while minimizing radiation to surrounding healthy tissues. In this sense, carbon ion beams that produce Bragg peaks in the body have ideal characteristics, as their ionization density increases with depth, so that the tumor at the peak is irradiated by the beam with higher RBE than healthy tissues at the plateau (Tepper 1977, Goldstein 1981).

1. Physical and Biological Properties

CIRT has unique properties in cancer therapy: 1) the Bragg peak allows selective irradiation of tumors, 2) it is effective for photon-resistant tumors, 3) hypo-fractionated irradiation is feasible in theory and in practice, 4) the risk of second cancers is not high, and 5) it is highly immunostimulatory.

A study of prostate cancer patients showed that the risk of developing second primary cancer after CIRT is not higher than after XRT or surgery(Mohamad 2019). Although secondary neutrons play an important role in the induction of second cancers, dosimetry confirmed that production of secondary neutrons is not higher with CIRT than with IMRT or proton therapy (Yonai 2014, 2018).

The LEM and MKM models have been employed to evaluate the biological effects of CIRT and to optimize treatment planning. For high-energy ion beams, RBE calculated by the LEM model tends to be overestimated compared to the MKM model (Fossatti 2018). Therefore, when comparing the dose effects of different facilities, it is important to note which of the two models was used to calculate the dose.

2. Clinical Study and Indications

In Japan, as part of the effort to combat cancer, Heavy Ion Medical Accelerator in Chiba (HIMAC) was built at NIRS (currently, QST) . Since 1994, HIMAC has played an important role in basic research in CIRT, biology and physics, and in development of new therapeutic techniques.

We have been conducting prospective clinical studies since the early 2010s to obtain insurance coverage for particle therapy; as of April 2023, CIRT is covered for tumors of the prostate, head and neck, bone and soft tissue, liver, pancreas, uterus, and colon (postoperative recurrence).

3. Charged Particle Therapy Worldwide

The number of proton and CIRT facilities worldwide is steadily increasing. As of early 2023, the total number of facilities in operation, under construction, or planned by country is topped by the U.S. with 56, followed by Japan with 27, China with 24, and Russia and the U.K. with 7 each, and so on. In terms of the number of facilities per 10 million population, Singapore has the highest at 5.1, followed by Norway with 3.6, Switzerland with 3.4, Taiwan with 2.6, etc. Emerging countries are likely to have significant growth potential in the future.

For further spread of charged particle therapy, downsizing of accelerators must be sought after. At QST, development of an accelerator called a "Quantum Scalpel" is in progress, which is expected to be completed as soon as possible.

The 2023 Bo Lindell Laureate Lecture: Assessing and Managing Radiological Risk

Ludovic VAILLANT (CEPN)*

Abstract–At low dose and low dose rate, the system of radiological protection developed by the ICRP is based on the linear non threshold relationship between dose and risk. Already, in *Publication* 9 (ICRP, 1966), the Commission stated ‘As the existence of a threshold dose in unknown, it has been assumed that even the smallest doses involve a proportionately small risk of malignancies […]. The Commission is aware that the assumptions of no threshold and of complete additivity of all doses may be incorrect, but is satisfied that they are unlikely to lead to the underestimation of risks’.

ICRP *Publication* 26 (ICRP, 1977), which laid down the basis of the current system of radiological protection, established a clear rationale between radiological risk assessment and radiological risk management. The effective dose concept was introduced along with wT based on the relative contribution of organs to radiological detriment. Dose limits values were directly supported by quantitative risk criteria. This rationale is somehow less clear (apparent) in *Publication* 60 (ICRP, 1991), which introduced a somehow less quantitative approach for radiological risk management, based on concepts such as tolerability, reasonableness or acceptable level of risk.

Over the last two decades, a number of scientific results have raised questions related to radiological risk assessment and consequences for risk management. This paper investigates some of these questions and potential consequences to be considered for the future of the system of radiological protection.

Mental Health and Psychosocial Support in Radiological and Nuclear Emergencies: Part 2 – NEA's Operational Extension

Julie BURTT (CNSC; ICRP C4; NEA EGNR)*, Matthias ZÄHRINGER (Retired BfS), Tristan BARR (Health Canada), Christiane PÖLZL-VIOL (BfS), Todd SMITH (NRC), Ian WALKER (DHSC), Jan-Hendrik KRUSE (OECD-NEA), Jacqueline GARNIER-LAPLACE (OECD-NEA)

Abstract–Lessons learned from past nuclear or radiological (N/R) emergencies have demonstrated that, similar to other large-scale disasters and emergency situations, the mental health and psychosocial consequences of an accident in terms of health detriment to affected populations can outweigh other public health impacts, e.g. radiation-induced physical health impacts such as cancer in the case of N/R emergencies. For this reason, in 2020, the World Health Organization (WHO) published a framework for mental health and psychosocial support (MHPSS) in radiological and nuclear emergencies as an initial step toward integrating mental health support and radiation protection. The present practical guidance, as an operational extension of the WHO framework, is intended to be action-oriented, and so takes the form of a summary table of actions, complemented by detailed action sheets where no specific guidance exists in available emergency guidelines to be adopted to N/R emergencies. The action sheets provide a list of preparation activities but also define indicators to help authorities assess their importance, quality of implementation, and efficiency. The general themes covered by the action sheets include: integrating MHPSS into needs assessments; coordination plans; public information; protecting staff and volunteers; training; health facility needs; decision-making protocols; public communication strategies; education materials; clinical referrals between medical and mental health care; services available in host communities; mental health monitoring; and social determinants of mental health.

Despite the extensive lessons learned from past N/R emergencies, more research is needed on how to effectively integrate MHPSS with radiological protection decisions. This includes integration prior to, during, and after any N/R emergency. Another aspect that deserves further investigation relates to optimisation in decision-making processes with inclusion of MHPSS during all emergency phases. In deciding what is the best solution for a protection strategy, the different risks, including the radiological risk, must be balanced, which requires a holistic approach. Any given circumstance will have social, economic, and political aspects that will influence stakeholders. Focusing on one single risk, for example radiation-induced health risks from radiation exposure, may lead to reduced radiological exposure, but not necessarily to a balanced overall protection of well-being. More generally, it has been understood and acknowledged for several years that the minimisation of one detrimental impact is always likely to result in something else detrimental not being minimised. Hence the need for a holistic view of optimisation, both as developed in radiological protection and as would be more widely understood by stakeholders.

Detailed planning, including resource planning and discipline integration, is vital for public health and safety. The structure and content of the practical guidance give insight into the complexity and interdisciplinary needs of N/R emergencies. It is vital to do "more good than harm" when protecting people and the environment against the potential harm of radiation.

Towards Well-being: Learning from Patient Experience and Interaction in ICRP TG109 Report

Marie Claire CANTONE (University of Milan)*, Kimberly APPLEGATE (University of Kentucky COM), on behalf of TG109

Abstract–The system of radiological protection for humans is based on the prevention of deterministic effects, keeping stochastic effects as low as reasonably achievable, taking into account economic and societal considerations, and at the same time considering that developments have been recognised towards the inclusion of further aspects of individual and well-being of exposed people, including psychosocial and mental health.

The Commission of Radiological Protection has relied on ethics as one of the three pillars, along with science and experience, in developing the system of radiological protection. ICRP Publication 138 has provided explicit guidance for how ethics is part of the system in helping to facilitate discussion in promoting the well-being of individuals and populations, and to balance further development of society with the protection of non-human biota in ecosystem. A clearer understanding of the core ethical values and how they relate to the key principles of radiological protection are recognised to help to address issue decision making across domains of radiation application. In practice, the search for reasonable levels of protection and tolerable exposure levels is an ongoing and evolving question that depends on the prevailing circumstances, ethical and cultural values.

In medical practice the procedures, in imaging and in therapy, continue to increase in number, variety and complexity. Striking a balance between the advantages of these applications and their potential harms, cannot be achieved by quantitative calculations alone. The art and practice of radiation in medicine seek health first, and practical situations often give rise to dilemmas that are best assessed on the basis of ethical criteria to promote patients' well-being and their best interests, as introduced in the ICRP report of TG109.

Medicine has a long history and culture regarding ethics, and the ICRP report of TG 109 emphasises the coherence between the values involved in biomedical ethics and those involved in radiological protection. The document proposes to clarify and define the key paired values: dignity/ autonomy; beneficence/ non-maleficence; prudence/ precaution; justice/ solidarity; transparency/ accountability/ honesty; inclusiveness/ empathy.

This approach allows radiological protection professionals to increase familiarity with the ethical in radiological protection. It also aims to assist medical professionals to integrate considerations of radiological science and protection into their ethical and clinical decision-making.

Regulators, equipment manufacturers, as well as managers of health facilities must be confident that the staff employed to work in these areas, have received the necessary education and are supported to maintain lifelong competencies. All radiological protection professionals must also understand the ethics of radiological protection in the use of radiation in medicine, as they will undoubtedly be confronted with ethical dilemmas and must be able to communicate with patients/family so that they may take responsibility in shared decision-making and/or communication with patients and the public. Medical clerks are often the first person the patients interact with the healthcare facility and sometimes they deal with patients' claims, thus education and training regarding communication and ethics would improve understanding and respect for cultural diversity, and individual decision making by the patient and family well-being.

Risk communication for recovery of the community in Fukushima

Noboru TAKAMURA (Nagasalo University)*, Hitomi MATSUNAGA (Nagasaki University),
Yuya KASHIWAZAKI (Nagasaki University), Makiko ORITA (Nagasaki University)

Abstract–Twelve years have passed since the accident at the Fukushima Daiichi Nuclear Power Station (FDNPS) in 2011. Since then, we have been assisting in reconstruction efforts for Kawauchi Village, Fukushima Prefecture, which was the first village to declare that residents could return to their hometown. In April 2013, Nagasaki University and the Kawauchi Government Office finalized an agreement of cooperation for reconstruction of the village. The university began comprehensive support for residents of the towns of Tomioka, Ohkuma, and Futaba in 2016, 2020, and 2021, respectively. Twelve years after the accident, gaps in the recovery process are apparent in all municipalities surrounding the FDNPS. After a nuclear disaster, radiation medical science experts need to fully understand the situation in each municipality in order to contribute most effectively to recovery.

Mesh-type Reference Computational Phantoms (MRCPs) for the Next General Recommendations

Yeon Soo YEOM (Yonsei University)*, Chan Hyeong KIM (Hanyang University), Chansoo CHOI (University of Florida), Bangho SHIN (Hanyang University), Suhyeon KIM (Hanyang University)

Abstract–A full set of ICRP Mesh-type Reference Computational Phantoms (MRCPs), including adult, pediatric, and pregnant-female phantoms, are under development to produce dose coefficients for next General Recommendations. The MRCPs are high-fidelity human models for radiation protection dosimetry, including all the source and target regions for effective dose calculations. The phantoms include micron-thick stem cell layers in the respiratory and alimentary tract organs, urinary bladder, and skin. The phantoms also include very detailed eye models and skeletal models. The MRCPs are developed in the 4th-generation phantom geometry, i.e., tetrahedron mesh geometry. This geometry, classified as unstructured volume mesh, provides several key advantages. Firstly, it allows the phantoms to be directly incorporated into various Monte Carlo codes, such as Geant4, MCNP6, PHITS, and EGS, without the need for voxelization. This preserves the original high fidelity of the mesh phantoms during dose calculations, ensuring the most accurate results. The tetrahedron mesh geometry is volume representation, not surface or boundary representation, and provides the capability of sub-organ/structure density variation modeling using the tetrahedrons. A notable aspect of the mesh technology is its flexibility, allowing the phantoms to be easily adjusted for different body shapes and postures as required. In the presentation, the deformability of the MRCPs will be highlighted by reporting that the MRCPs were deformed into a library of 212 phantoms for adults and 612 phantoms for adolescence and children to represent different body sizes and shapes. It will be also reported that the phantoms were deformed into several different postures.

Introduction of a New ICRU Report on Microdosimetry

Tatsuhiko SATO (Japan Atomic Energy Agency)*, on behalf of the Report Committee

Abstract–In 1983, the International Commission on Radiation Units and Measurements (ICRU) published Report 36, which provided the basic concepts, stochastic quantities and units appropriate to describe the probability distribution of energy deposition in microscopic sites. Since the publication, numerous studies have been devoted to improving the field of microdosimetry in terms of both measurements and computations. For example, many types of detectors have been developed for measuring the stochastic nature of energy deposition in micro- to nano-meter scale targets, in addition to low-pressure proportional counters that were widely used before 1983. Various new track-structure simulation codes have been developed and used for radiobiology research such as DNA damage yield estimation. Therefore, ICRU is considering publishing a new report entitled "Stochastic nature of radiation interactions: microdosimetry", which not only updates Report 36 but includes descriptions, analyses, and (whenever necessary) recommendations in a variety of aspects that constitute the recent progress of the field of microdosimetry. The contents of the report will be briefly introduced at the symposium, together with the comments on the possible role of microdosimetry in the dosimetry for the next general recommendations of ICRP.

The Next ICRP Recommendations: Dosimetry for Animals and Plants—Time for a Probabilistic Paradigm?

Alexander ULANOWSKI (International Atomic Energy Agency)*, Nina PETOUSSI-HENSS (German Federal Office for Radiation Protection), Tom HINTON (Norwegian University of Life Sciences)

Abstract–The next ICRP recommendations would benefit from the growing radiobiological evidence and improved dosimetry methods, resulting in a self-consistent, comprehensive and robust framework for radiological protection of humans, animals and plants on Earth and beyond. The current ICRP dosimetry system for animals and plants was pragmatically designed and implemented to address diversity of living forms in the environment, so as the dose coefficients were defined for exposure conditions described by idealized setups and for organisms represented as homogeneous bodies with simple shapes. For internal exposures, no radionuclide biokinetics were explicitly considered and the equilibrium concentration ratios were used as proxies for radionuclide uptake and retention. Protection endpoints for biota were defined at the level of populations and largely represented by the deterministic effects which can be observed in wildlife after radiation exposure.

Advancing the current dosimetry framework for non-human species by introducing more realistic and detailed models, in line with human-based approaches, could be often impractical due to the large diversity of non-human organisms, their living environments, biology, exposure conditions, radiobiological effects and protection endpoints. Populational and secular varieties of organisms and exposure conditions make point dose estimates less suitable for assessment of radiological impact and may require use of probabilistic methods, including dose distributions, populational and survival statistics. Such probabilistic frameworks, dealing with distributions of species, doses, environmental conditions, spatio-temporal properties of radiation sources, could be based on dosimetric data established for reference grids of organisms, exposure situations, sources, behavioral patterns, event timelines.

Improvement of dosimetry and introduction of new probabilistic techniques are required at most for terrestrial animals and plants, which demonstrate the highest variety of species and conditions of radiation exposure. For example, external exposure of wildlife to environmental sources of radiation may occur underground, on the ground, in air in open field, in forest, in river or lake. Conditions of radiation exposure in freshwater or brackish environments challenge the generic assumptions on infinite uniform sources used for aquatic organisms. Migration of animals through inhomogeneous radioactively contaminated environment results in strong variability of doses and can be described and operated in terms of dose distributions and probability of radiation-attributed impact on the animal population.

Development of new methods and datasets, which may contribute to the next ICRP recommendations, appears as an important goal, especially, in the field of dosimetry for animals and plants. In cooperation with the ICRP Committee 2, the International Atomic Energy Agency coordinates an international research project on external dosimetry methods for non-human organisms in the terrestrial environment, thus improving the knowledge base on environmental radiological protection.

Specific Absorbed Fractions for Reference Individuals for the Current and Next General Recommendations

Derek JOKISCH (Francis Marion University, Oak Ridge National Laboratory)*

Abstract–The calculation of doses to organs and tissues of interest due to internally emitting radionuclides requires knowledge of, amongst other quantities, the fraction of energy emitted from a source region which is absorbed per mass of a target region. This quantity is the specific absorbed fraction (SAF). Publication 133 contains SAF values for the reference adults and a forthcoming publication contains the same for the reference paediatric individuals along with explanations for their derivation and use. Computation of SAF values involves simulating radiation transport in computational models which represent the geometry of the reference individuals. The reference voxel phantoms of Publications 110 and 143 were used for photon and neutron transport and most of the electron transport. Additional computational models were used for charged particles in small, overlapping or interlaced geometries. SAF values developed for the next general recommendations will benefit from the development of mesh phantoms including those in Publication 145. Finally, additional opportunities for improvements to SAF values will be discussed.

The Fukushima Dialogue and Risk Communication

Jacques LOCHARD (Nagasaki University)*

Abstract–Since the first edition in November 2011 initiated by ICRP, 25 Fukushima dialogue meetings were held in 12 different municipalities of the Prefecture. A first series of 12 meetings organized and facilitated by ICRP was followed by a second series of 9 meetings organized by local residents but still facilitated by ICRP until the creation in 2018 of the NPO Fukushima Dialogue. Since then, the organization and facilitation of the dialogue meetings are fully in the hands of Fukushima local residents. Based on the Belarus experience in the 90s and 2000s as part of the rehabilitation of living conditions in the territories contaminated by the Chernobyl accident, the dialogue meetings are offering a fair and transparent forum to share experience not only between local residents, but also with experts, government officials, and people from various groups and organizations from Japan and abroad.

Dialogue meetings have so far enabled participants to exchange and discuss topics that affect them more or less directly in their confrontation with radioactivity. Although they are not intended to prepare decisions relating to the protection of people, the issue of radiation risk is however omnipresent in the background of the exchanges between the participants. If the major concern in the years following the accident was mainly focused on the protection against radiation over time the recovery question took precedence.

Several lessons can be drawn from the Fukushima Dialogue for risk communication. The successive meetings have highlighted the key role of listening and sharing the diverse, and sometimes divergent, points of view of the participants in mutual respect and equal opportunity as an effective way for them to form their own opinion of the situation and thus get out of the vagueness in which they had been until the accident. They also demonstrated that the best way to express views and concerns about the situation was to rely on testimonies and narratives of participants related to their daily life.

The dialogue meetings emphasized that the scientific discourse, however precise and substantiated it may be, is not sufficient to answer the questions and concerns of those affected by the accident. They confirmed that it is more important to exchange and share opinions on the basis of the feelings of the participants vis-à-vis the complex and stressful situations with which they are confronted than to exchange directly on the risk itself. Without combining it with ethical values linked to social justice, precautionary measures and human dignity, as well as the daily practical experience of those who reside in the affected areas, the expert discourse remains abstract and does not make sense and reassure participants. Finally, the Fukushima Dialogue clearly underlined that beyond the fear of radiation, the challenge after a nuclear accident is that the affected people gradually acquire a practical culture of radiation protection which helps them to regain their dignity and project themselves again to the future.

The Role of Effective Communication and Stakeholder Engagement in the Application of the System of Protection

Peter BRYANT (Sizewell C)*

Abstract–The ALARA principle, keeping the likelihood of incurring exposure, the number of people exposed and the magnitude of their individual doses 'as low as reasonably achievable, taking into account economic and societal factors', is at the core of radiation protection.

Historically the stakeholders involved in the application of the ALARA process have typically been internal to an organisation, such as an operator, and include a combination on both Radiation Protection (RP) Practitioners and Non RP Specialists. However, could there be instances when the public should be a key stakeholder in the decision making? And how understandable is the system of protection to those wider stakeholders?

This talks explores the role of effective communication in terms of both explaining radiation risk and the system of protection to the wide range of stakeholders who may be involved in decision making. It will pull on a number of case studies presented at a ICRP and World Nuclear Association Workshop on Communication held in Bristol in the UK on the 28th September. This includes case studies across the Nuclear Fuel Cycle including Uranium Mining, New Nuclear Build, Operators and Waste Management Facilities, from the perspective of Radiation Protection Professionals, Regulators, Academia and Journalists.

Learning from these case studies will be is used to highlight the key lessons learnt and the importance of effective communication and stakeholder engagement as part of the System of Protection.

HERCA's Perspectives on the Challenges of the Communication in Radiation Protection

Tommi TOIVONEN (HERCA)*

Abstract–HERCA (Heads of the European Radiological protection Competent Authorities) is an association which gathers European radiological protection authorities. A large part of the HERCA work consists of sharing experiences and best practices in order to learn from each other and by this enhance the level of radiological protection in Europe.

In May 2022 HERCA submitted the association's reflections on the Revision of the System of Radiological Protection, to ICRP. This paper was based on input from HERCA's members on experience in the practical application of the RP System in their organizations and countries. The input was collected in 2020 and supplemented in 2022. One of the four main topics of the document was communication.

This presentation will describe the views of HERCA's members regarding communication. HERCA acknowledges the great work done by ICRP and the challenges of covering the broad scope of the RP in one coherent system. Whereas the system has been found generally fit for purpose and scientifically solid, HERCA's members have also raised some concerns regarding communication. The main concerns were the overall complexity and communicability of the RP system. HERCA also found important to further elaborate the ways to communicate the risk and putting the radiation risk in the contexts of benefits and natural background.

Progress on Radiation Protection after Fukushima- Daiichi in the Spanish Nuclear Safety Council

Elvira ROMERA (Consejo de Seguridad Nuclear)*

Abstract–The Fukushima Daiichi accident raised several issues related to protecting people and the environment from ionizing radiation. Regularity authorities all over the world began to consider ways to enhance their systems of radiological protection, as well as strengthen their emergency response in case of a severe accident.

In this symposium, we will talk about the improvements that have been carried out at a regulatory level in radiological protection in the Spanish Nuclear Safety Council, as a result of the lessons learned from the accident at Fukushima Daiichi; particularly, we will talk about the regulations that have been modified and the technical instructions that have been issued due to this fact, focusing on the required measures related to radiation protection. These measures are the following: (i) actions to protect control room operators in nuclear installations, (ii) improvements on collecting samples in the event of an accident, (iii) improvements in the environmental radiation monitoring systems, (iv) personal protection of workers during nuclear and radiological emergencies. Regulatory requirements comprising improvements both in human performance and equipment in nuclear installations shall be analysed, emphasizing radiation protection aspects.

The experience of the Suetsugi Atlas: lessons for the implementation of the co-expertise process

Ryoko ANDO (NPO Fukushima Dialogue)*

Abstract–From 2011 to 2020, the collaborative and independent radiation measurement activity, inspired by the co-expertise approach, was implemented by residents and the citizen group 'Ethos in Fukushima' in the Suetsugi district, 27 km south of the Fukushima Daiichi nuclear power plant. The continued implementation of radiation protection practice by the resident nurtured by dialogue, measurements of radiation and independent decision-making has gradually brought back a sense of control over the territory among themselves.

As the series of measurement activities drew to a close, some residents expressed a desire to retain all of the information accumulated during the process. This led to the production of the 'Suetsugi Atlas' gathering the testimonies of inhabitants involved in the measurement activity as well as the results of the latter. The fifteen stories collected clearly demonstrate that the co-expertise process has enabled the residents concerned to regain autonomy and a sense of control in their daily lives.

However, they also show that some issues remained unresolved. First, the direct consequences of the accident in everyday life did not disappear with the disappearance of concern about the presence of radioactivity. Second, the feeling of injustice that was present throughout the process is still there despite the improvement in the radiological situation. Third, the information and sources that residents trust remain confined to the activities of their daily lives over which they have regained control.

The "Suetsugi Atlas" experience suggests the need for stakeholder involvement in decision-making that goes well beyond radiological protection. It also highlights the importance of recognizing the existing balance of power between the stakeholders in the affected areas, and finally the crucial role of sharing experience and transmitting memories.

The presentation aims to draw lessons from this original experience in more ways than one.

Solution-oriented Risk Governance Practices toward Reconstruction and Improved Wellbeing after the Fukushima Disaster

Michio MURAKAMI (Center for Infectious Disease Education and Research (CiDER), Osaka University)*

Abstract–The Fukushima disaster in March 2011, resulted in reduced wellbeing, in addition to radiation exposure and health effects such as diabetes and psychological distress [1]. I here emphasize the importance of focusing on efforts to improve wellbeing among affected people and on decision-making processes that are acceptable to people in the aftermath of a nuclear disaster. This importance is supported by research and practical examples from the aftermath of the Fukushima disaster. First, the diverse risks and benefits after the Fukushima disaster (e.g., radiation exposure, diabetes, psychological distress, and return) can be compared by using wellbeing as an outcome (i.e., loss or gain of happy life expectancy), providing implications for the optimization of radiation protection [2-4]. Second, interviews with risk communicators after the Fukushima disaster revealed the importance of restoring daily life, including improving wellbeing, as a top goal of risk communication practices [5]. Third, the regulations that had been implemented after the Fukushima disaster, such as food control and the lifting of evacuation orders, were based not simply on assurance of reasonable safety based on radiation exposure level, but on stakeholder consensus toward the improvement of people's sense of satisfaction and acceptance [6]. Fourth, procedural fairness and distributive fairness were the most important factors in the acceptance of final disposal sites for decontaminated soils generated after the Fukushima disaster [7, 8]. These examples can be organized as embodied in a solution-oriented risk governance practice [9] that emphasizes the improvement of wellbeing and a decision-making process that satisfies people, based on concepts related to optimization, stakeholder involvement, and justice that have been discussed in the field of radiation protection.

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Impact and Implications of Radiation/Nuclear Disasters on Public Health: A Focus on Evacuations and Disaster-Related Deaths

Masaharu TSUBOKURA (Fukushima Medical University)*

Abstract–Radiation or nuclear disasters carry multifaceted health consequences. These range from immediate health impacts due to radiation exposure to indirect ramifications stemming from evacuations, interruptions to the healthcare infrastructure, and shifting social dynamics.

Our research team extensively analyzed the risks associated with evacuating nursing homes and hospitals, using primary data from the Hamadori region of Fukushima Prefecture. Notably, within certain facilities, a staggering 25% of elderly residents were recorded to have passed away within a mere 90 days post-evacuation. When observing lost life expectancy, the evacuation led to a drastic 400-fold decrease when contrasted with potential radiation exposure had the elderly remained in place. When focusing on nursing home evacuations, the challenges extend beyond merely transporting bedridden patients. Issues such as discontinuation of care upon arrival at a new facility and the obstacles of information dissemination are significant. Detailed case studies on actual evacuations during the nuclear mishap revealed diverse challenges across different evacuation phases - from the onset of the disaster to the evacuation decision, and from that decision to the execution of the evacuation itself.

In Japan, "disaster-related deaths" is the term coined for indirect fatalities. Comprehensive research on such deaths in regions severely impacted by nuclear accidents has revealed that these deaths persist beyond the initial aftermath of the accident. Reports indicate their occurrence even after six months. Furthermore, these deaths can be classified into distinct patterns, underscoring the need for pattern-specific preventive interventions.

Post the Fukushima nuclear incident, Japan has moved towards favoring protective actions that minimize undue movement, such as in-place sheltering, during nuclear emergencies. Yet, challenges remain, including ensuring adequate personnel to care for vulnerable populations like the elderly, and ensuring consistent supply chains. This presentation delves into the challenges faced during evacuations post the Fukushima incident, and sheds light on Japan's subsequent policy shifts and the local adaptations to these new directives.

Preparing for Recovery from a Nuclear Accident: The NEA Preparedness Framework

Anne NISBET (UKHSA)*, Thierry SCHNEIDER (CEPN), Veronica SMITH (EPA)

Abstract–Twelve years after the Fukushima Daiichi accident, many lessons have been drawn that have improved the preparedness for nuclear emergencies. Some of the main lessons concern the multidimensional impacts of large-scale accidents, e.g., on health and wellbeing of the affected population, social life, the economy and the environment. Recovery is a long, complex and resource intensive process. While the development of efficient response plans as part of preparedness is well supported by international guidance, limited material exists for preparing for long-term recovery. To address this gap, in 2019 the Nuclear Energy Agency (NEA) established an expert group to develop a comprehensive and operational generic framework for post-nuclear accident recovery preparedness that can easily be adapted to national conditions. This framework was published in 2022 (NEA, 2022).

The process for establishing a preparedness framework should adopt an all-hazards approach that is risk informed, proportionate, flexible, scalable, and non-prescriptive. Governance, roles, responsibilities, and coordination should be anticipated, legal requirements considered, and international and/or transboundary harmonisation facilitated. The integration of ethical principles, such as prudence, justice, and dignity, is key to ensure that decisions are equitable and respectful of individual autonomy. Without plans in place to adapt to the capacity and capability demands of a situation, timely recovery will be inhibited, and the societal, economic, and psychosocial consequences will be greatly increased. Therefore, it is essential to build resilience involving relevant stakeholders during the preparedness phase, so that resources can be organised and mobilised to maximum effect, in the event of a radiation emergency.

The preparedness framework should also consider the objectives of recovery, namely, to ensure health and wellbeing, support for the economy, and protection of the environment. To achieve these objectives, decisions on protection should be holistic, inclusive, and sustainable, and made in close coordination with relevant stakeholders. The strategies to achieve the recovery objectives can be divided into cross-cutting components, comprising stakeholder engagement, communication and resilience building, and topical aspects, comprising food and drinking water management, remediation and decontamination, waste management, and monitoring and dose assessment.

This presentation will provide an overview of the recovery preparedness framework. It will then provide an example, relating to preparedness for remediation and decontamination, highlighting the important role of stakeholders in optimising decisions on the strategy selected.

[Cousins Award Finalist] A Biokinetic Model to Assess Radon Uptake by the Fetus in Pregnant Women

Ämilie DEGENHARDT (BfS)*, Vladmir SPIELMANN (BfS), Augusto GIUSSANI (BfS)

Abstract–Background: Epidemiological studies on residential exposures showed a statistically significant increase of lung cancer risk from prolonged exposure to indoor radon at levels of the order of 100 Bq.m-3. Current concern involves both male and female individuals that work in offices and facilities in radon prone areas. Pregnant women are an important group to be considered in radiation protection with exposures to radon and its progeny, occurring both in their working places and in their dwellings. It is important to highlight that post-conceptional exposures to ionizing radiation are still a topic of discussion for possibly causing heritable effects to the offspring.

Motivation: The aim of the study was to develop a comprehensive biokinetic model for radon to assess fetal uptake after radon intakes by the mother both through inhalation of radon gas and its progeny, and through ingestion of radon in drinking water.

Methods: The compartmental model was developed starting from the most recent ICRP age-and sex- specific biokinetic model for radon. The unknown parameters were determined with the software SAAM II based on published studies on animal and human pregnant individuals exposed to ^{222}Rn, ^{133}Xe, and ^{85}Kr.

Results: The human alimentary tract model (HATM) was added to maternal systemic model to evaluate concomitant intakes of radon both through inhalation and ingestion. Although radon is a gas and it is mostly exhaled by the lungs, part of it can reach the placenta and fetal tissues, especially fatty tissues (e.g. bone marrow). To evaluate fetal uptake 3 compartments were implemented to the model, the myometrium, the placenta and the fetus, based on studies run on pregnant women to evaluate placental washout of ^{133}Xe. Substructures in the fetus representing fat, red marrow, and yellow marrow were also considered based on the tissue concentration ratios between fetus and mother CF:CM. Regarding radon progeny, information from animal studies on lead and bismuth placental transfer and direct translocation of lead from maternal skeleton to fetal tissues were considered.

Conclusions: The proposed model gives a realistic description of the available biokinetic data for radon based on human and animal data to assess fetal uptake of radon and progeny due to maternal exposures.

[Cousins Award Finalist] PregiDose: A Mobile Application Designed Through a User-Centered Approach to Enhance Fetal Dosimetry and Wellbeing Among Pregnant Radiographers

Hafsa ESSOP (University of Pretoria)*, Mable KEKANA (University of Pretoria), Hanlie SMUTS (University of Pretoria)

Abstract–Pregnant radiographers require more stringent radiation dose monitoring than general radiographers, due to the sensitive nature of a developing fetus's cells towards radiation. Occupational radiation safety measures are outlined for pregnant radiographers, such as limited practice in high radiation areas as well as the use of personal dosimeters to monitor and record fetal doses, to ensure that the maximum threshold of 1mSv of radiation is not exceeded. Compliance towards pregnancy dosimetry is very low in South Africa, with many pregnant radiographers not receiving any dosimetry support such as training on the dosimeter. This has led to the under-utilization of the personal dosimeter and absence of fetal dose records among pregnant radiographers. This gap in fetal dosimetry called for the development of an intervention suited to the new technological generation, such as a mobile application.

Methodology: This study was executed in two phases. The first phase was a situational analysis on fetal dosimetry among pregnant radiographers in South Africa, using a survey. The second phase was a Participatory Design Workshop (PDW) with a panel of twelve participants, who have an association with the research area, such as currently and previously pregnant radiographers, medical physicists, quality assurance managers, the Radiation regulatory board of South Africa among others. A Design Thinking approach and FIGMA tool, was used during the PDW, encompassing five steps, namely Empathy, Define, Ideate, Prototype and Test, to develop a prototype mobile application, tailor made for the pregnant radiographer.

Results: Phase one: The situational analysis revealed that only 56% of pregnant radiographers "always wore" there personal dosimeters. An alarming 52% never consistently recorded their fetal dosimeters and 74% never received training on their personal dosimeters.

Phase two: Using the Design Thinking process, it was revealed that pregnant radiographers do not understand how the dosimeters are used, which negatively impacts accurate dose measuring. Further pregnant radiographers have a lack of understanding of radiation effects towards the developing fetus, making them complacent towards effective fetal dose record keeping. It was also revealed that pregnant radiographers feel isolated and "useless" in the workforce. In the ideate phase, the panel designed a prototype mobile application named "PregiDose". This mobile application has features such as daily dose recordings, whereby dose measurements from the personal dosimeter can be imputed in the mobile application. Weekly and monthly dose reports can be generated, that can be also be accessed by the radiation regulatory board of South Africa. Other features include education links to dosimeter service providers as well as ICRP and IAEA pregnant radiographer guidelines. The panel also honed in on the emotional wellbeing of a pregnant radiographer, by including features of journaling, finding a pregnant radiographers friend, motivational reading and exercise links.

Conclusion: The prototype mobile application, PregiDose was developed through a user-centered approach. The features recommended by the panel address educational and emotional needs of the pregnant radiographer, which provides an innovative, effective and holistic way of ensuring occupational radiation safety for this vulnerable, under-represented population of radiographers.

[Cousins Award Finalist] Rethinking Tissue Reactions to Radiation: The Tissue-Sparing Effect as a Threshold for Radiation-Induced Male Infertility

Hisanori FUKUNAGA (Hokkaido University)*, Kevin PRISE (Queen's University Belfast)

Abstract–Radiation-related effects at the tissue level appear to be dose-dependent; however, notable differences exist in the responses observed, depending on whether the radiation exposure is uniform. The principle of microbeam radiotherapy (MRT) is the delivery a single high-dose fraction to a large treatment area divided into several smaller fields, to reduce the treatment's overall toxicity. Since the fundamental concept of MRT was first established, a notable tissue-sparing effect (TSE) has been confirmed in a large variety of species and tissue types, though the underlying biological mechanism in this process remains obscure. By coupling high-precision MRT with an ex vivo mouse spermatogenesis model, we demonstrated the significant testicular TSE for maintaining spermatogenesis following spatially fractionated microbeam irradiation. To our knowledge, this was the first TSE identified in reproductive tissue. Our high-precision microbeam analysis also revealed that an efficient TSE for spermatogenesis relies on the size of the non-irradiated germ stem cell pool in the irradiated testicular tissues, suggesting the involvement of stem cell migration/competition. These findings suggest that, to preserve male fertility, the distribution of doses irradiated in testicular tissue at the microscale level is clinically important when considering the delivery of high-dose radiation. In addition, from the radiological protection perspective, one of the key characteristics of this testicular TSE cannot be overlooked: it is not a dose-dependent response. Traditionally, radiation-induced infertility associated with testicular exposure has been thought to be a dose-dependent tissue reaction. However, our findings of testicular TSE indicate that radiation infertility is not dose-dependent, but instead depends on microdosimetric conditions. In other words, the limit of the TSE is potential threshold for radiation-induced male infertility. Such a paradigm shift may be powerfully driven by the further accumulation of experimental data in stem cell biology using microbeams. Further, it would call for a reconsideration of future radiological protection systems. This novel concept may be common, not only in radiation-induced male infertility but also, in other tissue reactions to radiation.

[Cousins Award Finalist] To Leave or Not to Leave: A Tiered Assessment of the Impacts of Scale Residue from Decommissioned Offshore Oil and Gas Infrastructure in Australia

Amy MACINTOSH (Macquarie University & ANSTO)*, Tom CRESSWELL (ANSTO), Darren KOPPEL (AIMS), Gillian HIRTH (ARPANSA), Rick TINKER (ARPANSA), Katherine DAFFORN (Macquarie University), Anthony CHARITON (Macquarie University), Beth PENROSE (CDU, RINA), Andrew LANGENDAM (Australian Synchrotron)

Abstract–There are a range of potential options for the decommissioning of offshore petroleum infrastructure, including: complete removal; removal of topside infrastructure with subsea infrastructure left in situ; or partial removal or modification of infrastructure.

The current decommissioning liability in Australia is estimated to exceed US$40 billion over the next 50 years. This is founded on the base-case regulatory position of complete removal of all infrastructure, with over half the liability occurring in the next 10 years. In Australia, a recently updated decommissioning framework requires that the planning for decommissioning begins from the outset of the project, and plans are matured throughout the life of operations.

Successful decommissioning of subsea oil and gas infrastructure requires an effective and safe approach for assessing and managing chemical and radiological residues. Naturally occurring radioactive materials (NORM) are ubiquitous in oil and gas reservoirs around the world and may form contamination products including scales and sludges in topside and subsea infrastructure. In situ decommissioning of infrastructure left in the marine environment has many ecological benefits including establishment of artificial reefs, economic benefits from associated fisheries, reduced costs and improved human safety outcomes. However, there may be ecological risks associated with leaving infrastructures in the marine environment that are not well understood.

Following a scenario of in situ decommissioning of subsea petroleum infrastructure, marine organisms occupying the exteriors or interiors of production pipelines may have close contact with the scale (metal and radionuclide contaminants). Consequently, radio- and chemo-toxicological effects from the scale could occur respectively. This paper considers the current assessment process for NORM-contamination products in oil and gas systems, recent and emerging Australian research in marine radioecology. Here we demonstrate a tiered approach to assess the ecological impacts of pipeline scale related to decommissioning practices, and identifies key research priorities. This can further aid our understanding of the fate of NORM contaminates in subsea oil and gas systems and guide Australia-specific (expand to other petroleum operating countries) risk assessments for infrastructure decommissioning options. The creation of a tiered assessment will enable industry to optimise decommissioning solutions and allow regulators to set clearer expectations on the requirements for environmental protection.

The Future of Radiation Protection for Young Professionals with Experiences of the IRPA Young Generation Network

Takahiko KONO (The Leadership Committee of the IRPA Young Generation Network, Young Researchers' Association and Japan Health Physics Society)*, Sylvain ANDRESZ (IRPA-YGN and NPEC, Chair of the IRPA YGN), Christy BETOS (IRPA-YGN, PNRI), Yeon Soo YEOM (IRPA-YGN, Yonsei University), Tahar Hamida BASHIR (IRPA-YGN, National Center for Nuclear Sciences and Technologies), S. HUSSAIN (IRPA-YGN, Nigerian Army Medical Corps), Franz KABRT (IRPA-YGN and AGES), Omar NUSRAT (IRPA-YGN, Ontario Tech University), Anna MICHAELIDESOVA (IRPA-YGN, Czech Technical University), Thiago V. M. LIMA (IRPA-YGN, LUKS), Nona MOVSISYAN (IRPA-YGN, Center for Ecological-Noosphere Studies), Francis OTOO (IRPA-YGN, Radiation Protection Institute, Ghana Atomic Energy Commission), Cinthia PAPP (IRPA-YGN, National Commission of Atomic Energy), Joël PIECHOTKA (IRPA-YGN, Bundeswehr Zentralkrankenhaus Koblenz), Rui QIU (Tsinghua University), Marina Sáez MUÑOZ (IRPA-YGN, Universitat Politècnica de València, Secretariat of the IRPA YGN), Kazuji MIWA (IRPA-YGN, Japan Radioisotope Association), V.P. SINGH (IRPA-YGN, Karnatak University), Innocent TSORXE (IRPA-YGN, Duke University Medical Center), Kevin L NELSON (Mayo Clinic, Phoenix, IRPA Excutive Council), Hiroko YOSHIDA (Tohoku University, IRPA Excutive Council)

Abstract–Since its establishment in 2018, the Young Generation Network (YGN) has been dedicated, with support of the International Radiation Protection Association (IRPA), to a variety of activities to promote communication, collaboration and professional development of students, young professionals and scientists in radiation protection and its allied fields. This presentation will report on the activities performed from the middle of 2018 to 2023, with highlights on some important events, collaborations and publications. The experiences obtained from each activity will be summarized and used to inform how the IRPA YGN will aim to achieve its on-going activities and continue to follow the ways paved in the current Strategic Agenda 2022-2024 despite the very specific challenges faced by a "young generation network". Namely, extending the network, finding new relationships with networks with an interest in the young generation and participation in (remote) events will be aspired for. Whether local or global, the future of radiological protection relies on the contribution of young professionals. Sharing ideas, experiences, achievements and developing good relationships are vital to this network. Therefore, we hope to continue various regional or international events in the future, with the support of IRPA and its Associate Societies.

What Does Social Science Have to Do with Radiation Protection?

Maren GRUß (Federal Office for Radiation Protection (BfS) & ICRP)*

Abstract–Interdisciplinary research is of increased importance, especially in radiation protection. While it is inherent in radiation risk research to encompass various natural science disciplines, social sciences have only recently come more into the focus.

The contributions that social sciences can make are quite diverse. Social sciences deal with the basic principles of human coexistence, ranging from relationships, to organizations, all the way to complex systems. When examining the human element in radiation protection more closely, several challenges unveil: the challenge to create awareness and an understanding of radiation risks within the public, followed by understanding the publics' perception of risks as well as their concerns, and engaging different stakeholders in complex decision-making processes. These are just a few areas in which a deeper understanding of human perception and behaviour can significantly advance radiation protection.

Research on communication and stakeholder engagement focus on these challenges and to seek and find solutions to enhance the protection of people and environment regarding radiation risks is key. An exemplary case of interdisciplinary collaboration in radiation protection is the integration of crisis communication as essential part of emergency management. Therefore, TG120 has assigned two mentees to compile recommendations for crisis communication and engagement. Sociological insights into the principles of effective crisis communication assist in conveying possibly life-saving information before, during, and after a radiation emergency or malicious event to the public as well as increasing the publics willingness to comply with the instructions of authorities.

This presentation aims to provide a systematic overview of the challenges that social sciences address in radiation protection, as well as various solutions focusing on radiation emergencies and malicious events. Insights into the work as a Mentee of ICRP Task Group 120 highlight the special role of interdisciplinary exchange for the system of radiation protection.

Individual Differences in Medical Radiation Exposure in CT Dosimetry Based on Age and BMI

Weishan CHANG (Tokyo Metropolitan University)*

Abstract–Exposure settings should vary with patients to have an acceptable quality image with an appropriate patient dose. To manage medical exposure from computed tomography (CT), the size-specific dose estimates (SSDE) have been recommended to replace the volume computed tomography dose index because it considers patient size. However, organ dose is deemed more appropriate in the radiation protection field due to its correlation with radiation risk.

In this presentation, the difference in medical radiation exposure in CT based on Age and BMI by using the web-based computed tomography (CT) dose calculator WAZA-ARIv2 and dosimetry system of radiophotoluminescence dosimeters (RGD) and anthropomorphic phantoms will be introduced. In addition, the feasibility of BMI-based and age-based correction methods for organ dose estimation will also be investigated. For both BMI-based and age-based correction methods, the SSDE-associated correction factors showed consistency with the experimental results. Implementation of the SSDE-associated correction factors to the CT dosimetry systems is feasible and that organ dose estimation accuracy can be improved by applying these two correction methods.

Individualizing Radiation Cancer Risk: Insights From Animal Studies

Tatsuhiko IMAOKA (National Institutes for Quantum Science and Technology (QST))*, Kento NAGATA (QST), Yuzuki NAKAMURA (QST), Yukiko NISHIMURA (QST), Masaru TAKABATAKE (QST), Yutaka YAMADA (QST), Michiaki KAI (Nippon Bunri University), Kazuhiro DAINO (QST), Mayumi NISHIMURA (QST), Yoshiya SHIMADA (IES), Shizuko KAKINUMA (QST)

Abstract–Cancer risk is influenced by age and sex, as well as environmental and genetic factors. Epidemiology has attempted to characterize their impacts on radiation cancer risk, although the evidence is limited due to various difficulties. Animal studies complement epidemiology by identifying priority areas and adding cross-species and mechanistic perspectives.

As part of the work of Task Group 111, a systematic review was conducted to consolidate relevant evidence from animal studies. Most studies report results of qualitative analyses, with some reporting good quantitative evidence. Key findings include:

(1) Age and sex. Early age at exposure is associated with high risk, with variability among organs. Attained age generally increases the excess absolute risk (EAR) and decreases the excess relative risk (ERR). Females are more susceptible regarding the risk of all tumors.

(2) Lifestyle. Smoking and ^{239}Pu inhalation show a supra-additive interaction. Diet-induced overweight increases leukemia and solid cancers in exposed animals. Parity and hormones modify radiation-induced breast cancer and ^{90}Sr-induced bone cancer.

(3) Underlying conditions. Chronic inflammation increases tumors in some radiation-induced models.

(4) Other environmental factors. Interactions between chemicals and radiation range from additivity to supra-additivity. Some antioxidants and food components reduce radiation carcinogenesis.

(5) Genetics. Evidence suggests considerable impacts of the strain and genetic defects relevant to human tumor syndromes and DNA repair.

We re-analyzed our previous data from experiments using rat models of breast cancer in the presence or absence of radiation and lifestyle/genetic factors. Exposure at peripubertal age was the most potent in increasing breast cancer incidence, supporting a recent epidemiologic finding. The ERR per Gy decreased, whereas the EAR per Gy increased, with attained age. Dietary fat showed a supra-multiplicative interaction with radiation, carcinogenic chemicals showed a multiplicative interaction, and parity showed interactions that did not depart significantly from additivity or multiplicativity. A resistant genetic trait showed a quasi-multiplicative interaction. A *Brca1* knockout allele enhanced mammary carcinogenesis in response to radiation.

To gain cross-species insights from a mechanistic perspective, we used a multistage carcinogenesis model assuming a mutational effect of radiation, to analyze the cancer mortality data from the LSS cohort and an experiment conducted at QST/NIRS. Theoretically, the model predicts that radiation exposure chronologically shifts the age-related increase in cancer by a time in which the spontaneous mutational process would achieve the same mutational burden as the exposure. This model was fitted to both human and mouse data and suggested a linear dose response of the time shift that was 2 orders of magnitude greater in humans, consistent with the species-specific somatic mutation rates. The age-at-exposure effect was identical on a per-lifespan basis, and the attained age effect was not present.

These findings showcase heterogeneous interactions between radiation and various modifiers and highlight priority areas for epidemiology. More rigorous analyses with biologically based models will delineate the mechanism underlying the species difference in the radiation-associated cancer risk and its modifications.

The Case for Individualisation of Radiological Protection in Medicine

Colin MARTIN (University of Glasgow)*

Abstract–The use of radiation for imaging in medicine has become a key part of patient management. Medical exposures make up the largest component of exposure to the population from artificial radiation sources. Patient safety is an integral part of healthcare, so any potential harm should be considered when using radiological techniques. Measurable dose quantities employed in medical imaging do not reflect the likelihood of harm to a patient. This has led to adoption of effective dose, which takes account of radiation risk from stochastic effects derived from epidemiological studies, and this has become an accepted part of radiological practice. Effective dose has provided the basis for evaluating and controlling potential risks from different applications, and setting of dose limits for occupational and public exposure. However, since lifetime risks of stochastic effects vary by a factor of five or more with age at exposure, sex and population group, effective dose does not accurately reflect the harm for an individual. For occupational and public exposures, a detailed knowledge about the radiation fields and exposure configurations is seldom available. However, the situation for most medical imaging exposures is known and there is potential to have more accurate data on organ and tissue doses, particularly from computed tomography (CT) scans, which are the largest contributor to the overall population dose from medical applications. Moreover, in the long term doses could be derived directly from organ shapes and positions in each scan. Currently dose management software is often used to evaluate organ doses from CT scans for reference phantoms. These are not accurate representations of organ doses, since they do not take the size of the patient into account, but are used to calculate values for effective dose and are summed to derive cumulative values by some practitioners. However, libraries of anatomical phantoms of varying size are available that can be matched to the stature of individual patients allowing more realistic estimates of doses to each organ. Their use should provide better dosimetry data for medical epidemiological studies in the future. The best assessments of organ doses could then be combined with age and sex specific dose coefficients to derive risks. However, lists of organ doses for individuals do not readily translate into a quantity that is useful for educating healthcare staff about radiation risk. Within medical imaging communities there is an increasing desire to have a more accurate indicator of risk that can be applied to individuals and used in enhancing patient safety. Since software is being developed through which such individualised doses are achievable, it would be timely for the ICRP to provide guidance on the application of such a dose quantity within the overall system of radiological protection, at least for medical patients. Support for the creation of a single dose quantity for individuals related to radiation risk would allow the development of software along recommended lines, avoid a proliferation of methodologies, and provide an invaluable tool for education of the medical community.

Doses and Risks in Common Medical Examinations – Impact of Age and Sex

Richard WAKEFORD (The University of Manchester)*

Abstract–The absorbed dose (SI unit, gray) is the physical measure of energy deposited by ionizing radiation in a unit mass of matter, 1 Gy = 1 J/kg. However, ionizing radiation deposits energy in a microscopically localized manner, producing "clustered" damage to cellular DNA, and this must be taken into account when assessing the risks of adverse stochastic health effects (cancers and hereditary disease) arising from low-level exposure to radiation. Densely ionizing radiations produce more localized damage per unit absorbed dose than sparsely ionizing radiations, and the measure of the consequences is the relative biological effectiveness (RBE). In terms of the ICRP system of radiological protection, the RBE is accounted for through the radiation weighting factor, wR, which is applied to the absorbed dose to produce the equivalent dose (SI unit, seivert). Further, all tissues are not equally susceptible to the cellular damage produced by ionizing radiation, and in the ICRP system this is accounted for through the tissue weighting factor, wT, which is applied to the equivalent dose received by a specific tissue. When these tissue-weighted equivalent doses are summed over the whole body following an exposure, this generates the effective dose (SI unit, seivert), which is the basic dose quantity used in the ICRP system of radiological protection against low-level exposures. However, the effective dose must be related to the risk of stochastic effects, and this is not a straightforward process. The ICRP aims to produce a system that is globally applicable and is also practicable. To achieve this, organ/tissue-specific risk models, primarily obtained from the experience of the Japanese atomic bomb survivors, are generated, which are dependent on sex and age. For radiological protection purposes, the results of the application of these risk models are averaged over sex, age and population to produce risk coefficients (risk per tissue absorbed dose) for each stochastic effect (type of cancer or hereditary effect), which are then weighted by factors representing health impact to produce detriment values. It is the overall detriment that is related to effective dose for the purposes of radiological protection. Thus, the ICRP system addresses an "average world population", but not specific individual risks. Although effective dose is frequently calculated for a particular diagnostic medical exposure of a specific individual, the risk of stochastic effects depends on sex and age-at-exposure, among other factors, and on the distribution of tissue absorbed doses. Therefore, one cannot just naively apply a risk of "5% per Sv", broadly obtained by ICRP as a world average, but important factors must be taken into account in assessing individual risk. This can be done relatively simply using ICRP organ/tissue-specific risk models and organ/tissue absorbed doses, to give an approximate risk of stochastic effects per effective dose for the particular medical procedure and the specific individual. It is probably not feasible to go much further than this because of the presence of other factors influencing risk that have not been taken into account in the calculation.

Ensuring that Environmental Radiological Protection Remains Fit for Purpose and Science Based: Ongoing Work of Task Groups 99 and 105

Christelle ADAM-GUILLERMIN (IRSN)*, Jacqueline GARNIER-LAPLACE (NEA), Andy MAYALL (Environment Agency), David COPPLESTONE (Universiry of Stirling)

Abstract–Protection of the environment including the protection of non-human biota from the harmful effects of exposure to ionising radiation will be an important consideration of the next General Recommendations of the International Commission on Radiological Protection (ICRP). The environmental radiological protection framework was established by the ICRP about 15 years ago and given its relative infancy there remain areas for potential improvement. For example, broadening the representativeness of Reference Animals and Plants (RAP) from the taxonomic family to the class level, better substantiation of the Derived Consideration Reference Levels (DCRLs) using the latest radiobiological and radioecological effects data and using systematic methods for the derivation of DCRLs that reduce the reliance on expert judgement.

Extrapolation of the most up to date effects data was used to determine the range of radiosensitivity of population-relevant effects (or endpoints) within a taxonomic class - termed the Endpoint Sensitivity Distribution (ESD) – with the uncertainties quantified as far as possible. For a given taxonomic class, the DCRL is the band of absorbed dose rates (expressed in µGy/h) where deleterious population-relevant endpoints may occur in organisms of that class. Task Group 99 (TG99) proposes that the upper bound of the DCRL range be set at the best estimate of the 5th percentile of the ESD. The lower bound is obtained by dividing the upper bound by an extrapolation factor to account for the quality of the dataset.

Task Group 99 suggests that the lower bound of the DCRL could be used in environmental radiological impact assessment as an exposure criterion for planned exposure situations. In existing exposure situations TG99 proposes that the full DCRL range be used to guide optimization decisions. For exposure situations where non-human biota may be acutely exposed such as in the early phase of a large accidental release of radionuclides, TG99 proposes that the Endpoint Sensitivity Distribution could be used to help understand the potential ecological consequences of such exposure.

The potential application of the proposed DCRLs will be tested by Task Group 105 and the overall implications evaluated prior to finalizing the approach.

Environmental Radiological Impacts of the Nuclear Industry from Mining, to Construction, Operation and Decommissioning of a Power Station

Peter BRYANT (Sizewell C / World Nuclear Association)*, Jim HONDROS (World Nuclear Association)

Abstract–The nuclear industry has had a good track record of progressively reducing occupational, public and environmental exposures across the nuclear fuel cycle through the practical implementation of the ALARA principle. Worker and public doses remain low and environmental impacts are being better understood, although the environmental impacts continue to also be low.

However, more recently, the industry is concerned that there is constant external pressure to continue to reduce exposures despite there being no justifiable reason. This results in radiation being prioritised above other potential hazards and leads to misallocation of resources (including physical, human and financial). The broader concern is that this downward pressure re-enforces the perception of risk at very low exposure levels and biases decision making about the benefits of the nuclear fuel cycle.

With the ongoing concerns of climate change, many countries have made a commitment to embrace low carbon energy systems. In support of this ambition new nuclear power has been identified as a key part of the energy mix, highlighting the need to ensure that the decision-making mechanisms at low dose and exposure levels do not constrain the global needs and that there is a balanced treatment of the radiological risk of nuclear power, taking into account the wider non radiological hazards, environmental considerations, and societal impacts.

This talk will explore the radiological impacts to the environment across the nuclear fuel cycle from mining to the design, construction, operation and decommissioning of new nuclear plants, and finally the management of radioactive liabilities (including spent fuel and radioactive waste). The talk will provide real life examples showing how the System of Radiological Protection in applied and how its over application leads to unsustainable outcomes.

Classification of Harmful Radiation-induced Effects on Human Health for Radiological Protection Purposes: History and Concepts

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Abstract– The classification of harmful radiation-induced effects into "stochastic" and "deterministic", or "cancer/heritable effects" and "tissue reactions" goes back to the 1950s. Until then, the International Commission on Radiological Protection (ICRP) and similar organisations took it for granted that the most important radiation effects on human health, such as skin reactions and suppression of haematopoiesis, occurred only if a specific "threshold dose" was exceeded. Accumulating evidence from animal experiments then suggested that germline mutations were induced proportional to dose without indicating a threshold. It was therefore considered "prudent" (ICRP 1, 1959) to work with a "linear no-threshold model", which was in due course also found to be most applicable and recommendable for the induction of cancer (ICRP 9, 1966). Cancer and heritable effects were termed "stochastic" because of the probabilistic nature of their occurrence. The effects induced with a threshold dose were accordingly called "non-stochastic" until 1990 (ICRP 60), when the term "deterministic" was introduced. It is still used in the general recommendations of 2007 (ICRP 103), although ICRP also pointed out that because these effects are modifiable by different factors and thus not entirely pre-determined, the "directly descriptive term 'tissue reactions'" might be preferable.

Here, we will not go into the classification of effects itself, i.e., we will not discuss which effects for which reason should be termed "stochastic" or "deterministic". That, to some extent, will be addressed in a parallel presentation. We will instead emphasise the practical importance of the classification itself. The setting of dose limits is quite different for "deterministic" and "stochastic" effects. In the first case, provided reliable data regarding the threshold doses for radiation effects on a particular tissue are available, the dose limit is supposed to avoid harm completely. What has been sometimes overlooked in this context, however, is that there is always a distribution of sensitivities within a population, so that absolute safety cannot be guaranteed. ICRP 118 (2012) suggested using a "practical threshold", namely a dose at which only 1% of the exposed individuals would show the reaction. With "stochastic effects", setting dose limits (or constraint or reference values) is an even harder task. As mentioned above, the keyword is "prudence": the linear no-threshold model is assumed to apply, although direct evidence below a few tens of mSv is currently unavailable. The expected risks at the dose limit should still be "tolerable". And below the dose limit, optimisation must be aimed for: "exposures should be kept as low as reasonably achievable, taking into account economic and societal factors," which again is based on the "prudent" assumption that there is no threshold dose.

There are also other areas of radiological protection where things are made more apparent or more manageable by the distinction between "stochastic" and "deterministic" effects, or "cancer/heritable effects" and "tissue reaction". For instance, the radiation weighting factor wR is based on scientific evidence for cancer induction and heritable effects. The numerical values of wR (and thus the concept of organ equivalent dose) only apply for the protection against "stochastic effects". In contrast, ICRP has recommended that for the assessment of "tissue reactions", values of the Relative Biological Effectiveness (RBE) should be used. This is just an example of the necessity to consider the implications of any change in the classical classification of radiation effects for other parts of the system.

Is Cancer Risk of Radiation Probabilistic or Deterministic?

Nori NAKAMURA (Radiation Effects Research Foundation)*

Abstract–Radiation risk for cancer is classified into probabilistic effects because it has been thought that induction of oncogenic mutations is involved and hence it is a single cell event. However, there are two observations that cannot be explained by the mutation theory. One is parallel shifts of mouse survival curves toward younger ages after radiation exposures, and the other is a decreasing trend of relative risk with the increase of time since an exposure. Both are smoothly explained if it can only be assumed that radiation exposure causes earlier shift of the naturally occurring tumors. Importantly, past studies which claimed dose responses for the increase in the fraction of tumor-death individuals were classified into two types: either premature termination of the observations soon after the tumor mortality in the control group started to increase, or the frequency was "age-adjusted". In both instances, the results do not lend support to the induction theory of radiation carcinogenesis. In contrast, there are clear reports showing that the frequency of tumor death did not increase after observations of the whole life span. In short, all the past data indicate that radiation exposures do not induce cancers through induction of oncogenic mutations but induce inflammatory microenvironment favorable for the precancerous cells to grow better so as to form tumors earlier than usual. Because it seems unlikely that a single fast electron can induce an inflammatory response to the irradiated tissue, it is more reasonable that carcinogenic effect of radiation is classified into deterministic effects which is a response of a tissue.

Revisiting Radiation Dose-Response for Tissue Reactions

Haruyuki OGINO (Nuclear Regulation Authority)*, Nobuhiko BAN (Nuclear Regulation Authority)

Abstract–Health effects of radiation exposure are classified into stochastic effects and harmful tissue reactions in the system of radiological protection recommended by the International Commission on Radiological Protection (ICRP). It is assumed that there is no threshold dose for stochastic effects as cancer and heritable effects are considered to arise from a single mutated cell. On the other hand, tissue reactions are characterised by the presence of a threshold dose as they result from radiation damage of a population of cells. While the threshold dose is defined as the estimated dose for 1% incidence (ED1), it may be complicated by substantial baseline levels for diseases that develop with ageing in the absence of radiation exposure such as cataracts and circulatory diseases. It is stated in ICRP Publication 118 that ED1 refers to effects just starting to rise above the baseline levels in unirradiated, age-matched individuals, and in the case of circulatory diseases, to a dose which would increase the already high natural incidence or mortality by only 1%. This implicitly assumes that radiation has a unique mechanism of action in inducing circulatory disease; however, circumstantial evidence suggests that radiation is likely to act jointly with other risk factors to promote atherosclerosis. If we assume that radiation-induced subclinical damage is added to that resulting from other risk factors, the threshold dose could be decreased depending on the extent of the joint effect. This phenomenon might be seen in age-related diseases that result from the accumulation of subclinical damage, and it is inferred that radiation accelerates the development of these diseases in a dose-dependent manner.

Task Group 123: Classification of Harmful Radiation-induced Effects on Human Health for Radiological Protection Purposes

Liz AINSBURY (UKHSA)*, Ludovic VAILLANT (CEPN), Friedo ZÖLZER (University of South Bohemia), Omid AZIMZADEH (BfS), David BROWN (EDF), Agnès FRANCOIS (IRSN), Nobuyuki HAMADA (CRIEPI), Sophie JACOB (IRSN), Chunsheng LI (Health Canada), Michiya SASAKI (CRIEPI), Constantinos ZERVID (Mediterranean Hospital of Cyprus / University of Nicosia Medical School), Dominique LAURIER (IRSN), Thierry SCHNEIDER (CEPN)

Abstract–In the current system of radiological protection, tissue reactions are those defined as injury in populations of normal cells characterised by a threshold dose and an increase in the severity of the reaction as the dose is increased further. Stochastic effects are those resulting from damage in a single cell, such as cancer and heritable effects, for which the frequency but not severity increases with dose, and for which there is no threshold. The objectives of the system are to manage and control exposures to ionising radiation so that harmful tissue reactions are prevented, and the risks of stochastic effects are reduced to the extent reasonably achievable. As such, the classification of health effects into these two distinct categories directly underpins the implementation of the system of radiological protection.

In recent years, there has been debate regarding the adequacy of the current scheme for the classification of health effects with current scientific evidence, for example concerning radiation cataracts and circulatory system diseases. Recent publications, including those from ICRP, have highlighted the need for a review of the ICRP scheme for health effects classification.

Task Group 123 has been established to:

1. Clarify the rationale behind the current classification (based on a review of relevant ICRP Publications) and the primary protection objectives of the ICRP system.
2. Assess the reasons calling for an evolution, based both on a review of scientific literature and relevance for the radiological protection objectives; and,
3. If any evolution is deemed desirable from a scientific point of view, assess the impact on practical management of radiological risk with regards to the radiological protection system objectives, for both the prevention of harmful tissue reactions and the limitation of stochastic effects.

This presentation will outline the basis for the establishment of the Task Group and the outlined tasks, the key sources of uncertainties for consideration, for example, based on underlying mechanisms, individual sensitivity, and the different protection objectives in the various exposure situations; the agreed approach and timeline to tackle the above tasks, as well as and the links with and dependencies on the other on-going developments to the system being considered by the other ICRP Task Groups.

Is NORM always an Existing Exposure Situation?

Chris JONES (TG127, AWE)*

Abstract–Naturally Occurring Radioactive Material (NORM) is defined in ICRP Publication 103 as "radioactive material containing no significant amounts of radionuclides other than naturally occurring radionuclides." NORM acts as a source of radiation exposure both when within its originally 'natural' setting and form, and following man-made extraction and processing, which may be as a by-product of other industrial processes or in order to use the NORM for its radioactive or non-radioactive properties. Applying the concept of exposure situations as defined within the current ICRP system of radiological protection to these different scenarios can result in a significant amount of confusion, with some scenarios having characteristics of both existing and planned exposure situations. This confusion can lead to a negative impact on the effectiveness of the radiological protection controls applied as well as compound wider uncertainties about how to apply the system of protection, although it can also be argued that the results should be the same regardless of how the exposure is categorised and that some flexibility for law makers and regulators is beneficial. The NORM example illustrates one of the key challenges facing Task Group 127 in its consideration of exposure categories and situations: how to add clarity to reduce confusion whilst not removing flexibility within the system.

Some Issues in the Implementation of the Current System of Protection

Analia CANOBA (Autoridad Regulatoria Nuclear)*

Abstract–Although the current system of radiological protection is robust and has performed well, ICRP has embarked on a review and revision that will update the 2007 General Recommendations in ICRP Publication 103, to adapt to science evolution and changes in society, taking also into account the experience from the application of the system.

In this sense, some difficulties arise in the implementation of the current ICRP recommendations, both for regulators and for operators. It is important that these difficulties be identified in order to be analysed for the need for further clarification or guidance in the framework of the future general revision.

The objective of this paper is to present some issues from the experience of the implementation of the current system of protection in some existing exposure situations (EES), such as radon, NORM and consumer goods. The main issues identified deal with cases where exposure situations are difficult to classify; the categorization of occupational exposure and application of graded approach in EES; the implementation of reference levels from the point of view of regulators; the implementation of protection strategies in line with sustainability principles and safety requirements, addressing safety and an overall well-being. Finally, from a practical point of view, the need for simplication of the system of protection is needed, where possible.

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Connections between Categories of Exposure in the Hospital Setting

Lorenzo Nicola MAZZONI (Medical Physics Unit Prato-Pistoia, AUSL Toscana Centro)*

Abstract–Actions that ensure the radiation protection of staff and the public are often interconnected with those dedicated to the radiation protection of patients in hospital settings. For example, the staff radiation exposure in nuclear medicine and interventional radiology is related to the dose absorbed by the patient. In particular, it is important to underline that the justification for everyone's exposure is largely driven by patient benefit. In this scenario, provisions to protect staff and the public should not impair those to optimize patient exposure or, more generally, limit clinical outcome. This connection between different categories of exposure, which has been addressed in many ICRP publications, has changed and continues to change over the years as technology and medical practice evolve. For this reason, it requires periodic review to ensure that the optimization principle is applied for all, as well as protection provisions are fit for purposes.
In this talk some worker exposure pathways in some current radiological medical practices will be described, also reporting what is already provided in the main ICRP publications dedicated to this topic. The intent is to stimulate discussion to investigate if anything can be updated or improved in this area during the revision of the system of radiological protection.

Issues and Confusions in an Existing Exposure Situation after the Fukushima Accident

Hiroko YOSHIDA (TG127, Tohoku University)*

Abstract– The long-term phase after a large nuclear accident is considered as an existing exposure situation and is distinct from emergency exposure situations in the early and intermediate phases of the accident. One of the issues and confusions after the Fukushima accident is that it is not clear where the boundary from the intermediate phase to long-term phase is, and where the boundary from long-term phase to normal phase is. As indicated in the International Commission on Radiological Protection (ICRP) Publ.146, the transition from an emergency exposure situation to an existing exposure situation does not necessarily take place at the same time in all affected areas. The reality is more complex, even within a single municipality or region there are simultaneous transitions from emergency exposure situations to existing exposure situations and from existing exposure situations to normal (planned) situations. For example, in Iitate village, Odaka district in Minami-Soma city, Namie town, and so on, evacuation orders had been lifted in 2016-2017, except for the difficult-to-return areas. In Okuma town, which is close to the Fukushima Daiichi nuclear power plant, the evacuation order had been lifted on April 10, 2019 in the areas in preparation for the lifting of the evacuation order and in restricted residence area, and the evacuation order in the specified reconstruction and revitalization base, which was set in difficult-to-return areas, had been lifted on June 30, 2022. In the areas where the evacuation orders were lifted, residents returned home, resuming their original life and newly residents including children were settled as well. That is, it is a mixture of areas that are close to normal situations in the long-term phase, those in the beginning of the long-term phase, and those that in the transiting period from the intermediate to long-term phase. In these complex situations, not only 'responders off-site' but also many people have started to work in affected areas in a variety of occupations.

In planned situations, the restriction on individual doses can be applied at the planning stage, and the doses can be forecast so as to ensure that the constraint will not be exceeded, while with an existing exposure situation, reference level should be applied since a wider range of exposures may exist. The 2007 Recommendations in ICRP Publ.103 states N.A. for occupational exposure in an existing exposure situation with a following note. Exposures resulting from long-term remediation operations or from protracted employment in affected areas should be treated as part of planned occupational exposure, even though the source of radiation is 'existing'. However, this doesn't seem to be clearly stated in ICRP Publ.146 for responders off-site.

In this presentation, which is more protective for workers off-site in an existing exposure situation: whether exposure should be considered as public exposure or as planned occupational exposure will be discussed in line with fundamental principles to protect exposed workers and safety requirements.

Exposure Categories & Situations in the Current System of Radiation Protection: Main Challenges and IAEA's Activities to Assist its Members Sates in Addressing them

Olvido Guzmán LÓPEZ-OCÓN (IAEA)*, Miroslav PINAK (International Atomic Energy Agency)

Abstract–As stated in the Fundamental Safety Principles, "The fundamental safety objective is to protect people and the environment from harmful effects of ionizing radiation." IAEA Safety Standards Series No. GSR Part 3 General Safety Requirements, Radiation Protection and Safety of Radiation Sources, is the latest edition of the International Basic Safety Standards. These Standards take account of the findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the Recommendations of the International Commission on Radiological Protection (ICRP). As scientific considerations are only part of the basis for making decisions on protection and safety, GSR Part 3 also addresses the use of value judgements relating to the management of risks.

For the purpose of establishing practical requirements for protection and safety, GSR Part 3 distinguishes between three different types of exposure situations: planned exposure situations, emergency exposure situations and existing exposure situations. Together, these three types of exposure situations cover all situations of exposure for which GSR Part 3 applies. Additionally, GSR Part 3 applies to three categories of exposure: occupational, public and medical exposures.

The descriptions that are given in para. 1.20 of GSR Part 3 of the three types of exposure situation, which are based in those in ICRP 103 Publication, are not always sufficient to determine unequivocally which type of exposure situation applies for particular circumstances.

Many of the challenges related to types of exposures refer to the concept of existing exposure situations which was introduced by the ICRP Publication 103 as those type of exposure resulting from sources, natural or man-made, that already exist when a decision on control needs to be taken. The feature that this type of exposure includes a very wide range of exposures arising from radon, naturally occurring radioactive material, cosmic radiation, and from areas contaminated by past practices or as a result of a nuclear or radiological emergency, brings challenges in the consistency of managing all types of exposure situations.

Other example needing value judgement presenting challenges in the implementation is the transition from an emergency exposure situation to an existing exposure situation which may occur progressively over time; and some exposures due to natural sources which may have some characteristics of both planned exposure situations and existing exposure situations. In GSR Part 3, the most appropriate type of exposure situation for particular circumstances has been determined by taking practical considerations into account. For instance, the exposure of aircrew to cosmic radiation is considered under existing exposure situations but it presents exceptional circumstances which needs to be considered separately.

Based on the IAEA's experience in assisting its Member States in implementing IAEA Safety Standards and supporting guides on radiation and safety, the presentation will address some of the main challenges encountered in the practical implementation of the three categories of exposure and types of exposure situations, and how the IAEA is assisting its Member States in addressing them.

A Proposed Framework for Reasonable: Relationships, Rationale, and Resources

Nicole MARTINEZ (ICRP)*

Abstract–The work of Task Group 114 within the International Commission on Radiological Protection (ICRP) is focused on reasonableness and tolerability in the System of Radiological Protection. The terms "reasonableness" and "tolerability" hold significant roles within the framework of the System, and thus more detailed, clear, and practical guidance as to the meaning, intent, and application of these terms is being developed. The current perspective on "reasonableness" is that the focus should be on the process, controls, or actions rather than a specific numerical value. One proposed framework for considering "reasonableness" with respect to the process is the 3Rs approach: relationships, rationale, and resources. This includes, for example, fostering mutual trust and engaging in the co-expertise process (Relationships), developing solid reasoning for the approach (Rationale), and making responsible use of natural, technological, financial, or human resources (Resources). Although each situation will necessarily retain its complexity, the 3Rs framework is intended to help simplify and support a proportionate and collaborative approach to reflection on the factors that make up "reasonable."

Summary of the ICRP-WNA Workshop on Optimisation

Marcel LIPS (Kernkraftwerk Goesgen-Daeniken AG / WNA)*

Abstract–WNA hosted an ICRP workshop on "Optimization of Risk based on the All-Hazards Approach" and "Effective Communication of the System of Radiological Protection". This paper summarizes the All-Hazards Approach part. The workshop was part of the process of reviewing and revising ICRP's General Recommendations.

In the introductory session, ICRP referred to the ongoing work of TG114 aiming to prepare the considerations and basis needed for the development of future recommendations. ICRP also underlined the importance of carrying out the review and revision with all stakeholders. In addition, ICRP highlighted that the level of protection is not only a question of ionizing radiation. From an industry point of view, it was underpinned that the appropriate expertise must be incorporated into the review and revision for reasons of practicability and implementability. Unnecessary burdens must be prevented, so that nuclear power generation can help to prevent further climate change. From a regulatory perspective it was mentioned that broadening of optimization would maximize benefits and therefore focus should not only be on radiation. For practitioners non-harmonized or contradictory regulations in different fields might prevent an effective and broad all-hazards approach.

In the main session a series of examples for the application of the optimization principle were presented covering the whole nuclear fuel cycle. There were different common messages in these presentations: Radiation is only one of many hazards. With doses becoming lower, conventional risk become more important. A hazards analysis helps to prevent optimizing protection against one hazard at the expense of others. Promoting a graded approach will prevent moving beyond cautionary principles, especially when it comes to the application of the LNT model at very low doses. Policies and Standards must explicitly allow a graded and all-hazards approach.

The last session addressed future applications of optimization. Again, the need for a balanced optimization was highlighted. For the development of SMR's balanced regulations are needed. Robotics were mentioned for harsh and extreme environments.

The following insights summarized the workshop: ICRP is aware that radiation is not always a primary hazard and will endeavor to recognize that radiation is one of a number of hazards and risks. An all-hazards approach does not contradict sustainability. ICRP also realized the confusion among society about its concepts (limits/constraints/reference levels, exposure situations) and imbalances (expenditures in the millions for clearance with doses in the microSv/y range compared to well accepted doses from natural sources in the mSv/y range) and agreed to try reducing complexity to ensure that its system was practical, implementable and understandable to a wider audience. WNA offered to provide member support for any work groups. ICRP is not expected (nor IAEA) to develop a detailed all-embracing 'all-hazards approach' to protection. A clear up-front top-tier statement in the revised Recommendations recognizing that radiation cannot be considered in isolation and is just one of many hazards faced by workers, patients and the public would help regulators and practitioners broadening the optimization process.

How can Reasonableness and Tolerability be Considered in Implementing Optimisation in the Decision Making Process?

Jacqueline GARNIER-LAPLACE (OECD Nuclear Energy Agency)*, Jan-Hendrik KRUSE (NEA), Greg LAMARRE (NEA), Haidy TADROS (CNSC), Thierry SCHNEIDER (CEPN)

Abstract–Reasonableness and tolerability are key interrelated concepts implicit in the implementation of optimisation in decision making. The presentation will put the results of the third NEA Workshop on Stakeholder Involvement in Optimisation in Decision Making, organised by the NEA in Paris (5 to 7 September 2023), into the perspective of a broader view of optimization as it relates to radiological protection (RP) considerations. The main objective of the event is to identify the basis for a generic, multidimensional framework to support the optimisation process for decision makers in the nuclear sector. Thus, based on the three preparatory webinars, and past workshops on optimisation and stakeholder involvement, the RP-related analysis consists of consolidating the understanding of what is meant by optimisation in decision-making, how and where reasonableness and tolerability can be considered, how stakeholder perspectives can contribute to this and how the optimised decision-making process can be reflected into regulatory frameworks.

For the purposes of the workshop which is expected to bring together some 120 participants representing the various categories of stakeholders (e.g. representatives of civil society, international organisations, national authorities and governmental agencies, private sector, academia), the NEA and its Committee on Radiological Protection and Public Health have proposed that optimisation be understood as the process of approaching a problem in a way that is:

- holistic, by taking into account the complex interactions between economic, environmental, health, cultural and social aspects and balancing all aspects of each of the potential solutions;
- inclusive, by involving stakeholders in a way that maximises the degree of acceptability of the outcome, while ensuring transparency, equity and fairness of the process; and
- sustainable, by resulting in option(s) that are durable, feasible and contribute to the achievement of the United Nations Sustainable Development Goals.

While an optimised outcome will be unique to each situation, optimisation in the decision-making process should lead to a holistic, inclusive and sustainable decision that takes into account different risks and benefits in the context of the prevailing circumstances and aims to achieve the most reasonable outcome for all stakeholders and society as a whole.

The presentation will show how stakeholder involvement can help to ensure that principles governing reasonableness and tolerability are included in optimisation in the decision making process, noting that the scope of stakeholder involvement depends largely on how much the decision will impact a fraction or the entire society.

ICRP TG 114, Application of Tolerability and Reasonableness in the Medical Field

Marie Claire CANTONE (University of Milan)*, Sébastien BAECHLER (Federal Office of Public Health), Reinhard LOOSE (Hospital Nuremberg)

Abstract–Unique aspects of radiation protection for patients are recognised as medical exposure of patient is deliberative and voluntary, and the patient agrees or consents to a medical procedure using ionizing radiation. Benefits and harms are received by the same individual.

Dose limits do not apply to medical exposure, as it may hinder patients from receiving the required dose for diagnostic or therapeutic procedures.

The application of both principles of justification, as decision to deliver ionising radiation, and optimization, as process to deliver the appropriate dose, contribute to quality in healthcare, and both principles are linked to tolerability and reasonableness.

The principle of justification plays a key role for patient exposure within the concept of tolerability, considering that if the procedure for an individual patient is justified, then the radiological risk is tolerable.

The principle of optimization is implemented by defining reasonable measures to avoid intolerable adverse effects and by managing the dose to the patient.

Tolerability and reasonableness assume the presence of a radiation safety culture as policies, processes, quality assurance, and training. Radiation safety culture needs to encompass all stakeholders who could affect the exposure of a patient, including the patient her/himself. The development of a radiation safety culture requires an organisation which takes account of radiation protection and safety, good medical practice, and human factors.

It is important to know what is considered an intolerable level of risk from the patients' point of view. Patient perception of adverse effects and risk often differs from clinician perception, as impact on daily life, emotionally and socially. It depends on how risks and benefits of the medical exposure have been discussed. Providing relevant information to the patient is not always easy, but the process of shared decision-making can help understanding individual patients' needs. This process is a key element of patient-centredness, seeking a good cooperation of practitioner and patient, built on trust and empathy, and thus improving the clinical outcomes.

Based on the generic concept of quality in healthcare, the framework of Tolerability and Reasonableness for radiological protection in medical exposure of patients could rely on three dimensions: i) Appropriateness/Justification, ii) Radiation safety/Optimisation and iii) Patient-centredness. When the procedure is prescribed and performed by respecting those three dimensions, the radiation risk can reasonably be considered as tolerable.

Some specific topics require to be analysed in term of tolerability and reasonableness, as e.g.: -exposure of the embryo/fetus during patient pregnancy; -rare and complex examinations not included in referral guidelines; medico-legal examination; -population radiological screening; -patient request without related justification. Moreover, the introduction of scenarios on ethics in the medical field allows to discuss practical examples and to highlight the specificities of the application of tolerability and reasonableness.

Tolerability & Reasonableness: Views from IRPA

Bernard LE GUEN (International Radiation Protection Association (IRPA))*, Marie-Claire CHAPPLE (IRPA)

Abstract–A first ICRP initiative was launched in 2021 seeking responses on the ideas relating to the review of the System of Protection and the ICRP2021+1 symposium was an opportunity for open and transparent discussion. The International Radiation Protection Association (IRPA) has set up a Task Group firstly to inform Associate Societies (AS) about these initiatives, encouraging them to organise feedback through IRPA and independently, and secondly to consolidate views reflecting both areas of broad consensus and the spectrum of views of the profession. Most countries were in general approval of the revision; particularly appreciated were the recognition of the need to simplify and clarify the system, the importance of communication, and planned involvement of stakeholders.

A need for re-evaluation of the tolerability of dose and inferred risks in different exposure situations has been prioritised. There was agreement from several Societies in regard to combining constraints and reference levels, although another considered careful differentiating of limits, constraints & reference levels important to prevent tightening controls excessively and one urged caution over having limits only for planned exposures and suggested tolerability of exposure should distinguish between workers and public. Suggestions were made to ensure clarity rather than confusion and urge caution in changing values, considering criteria based on lifetime exposure, and supporting work to broaden application of risk criteria and limits to reflect all exposure situations.

Healthcare is the only radiation-using sector in which a tangible benefit is obtained from planned direct irradiation of human beings: the patient and their diagnosis or treatment take priority over radiation protection considerations; a challenge evidenced by the continuing rise in numbers of medical exposures and increasing numbers of patients receiving high cumulative radiation doses. In clinical practice, as in policy, the value of prudence states that avoiding risk is not an absolute. The ALARA approach and the patient exposure must be adjusted to the medical objective which is improving the quality of diagnostic or medical treatment. Integrating precaution about radiation risk in clinical decision-making and informed consent need to build decision rules into a managed care preauthorization program. Medical Ethics is already included in radiation safety but more awareness is needed in the training

In nuclear industry, a number of practical examples were provided as to how over-conservatism has had an adverse impact on Nuclear industry favoring justifying very low dose outcomes without a balanced consideration of optimisation and reasonableness with significant costs on industry.

In conclusion, based on all this examples, aspects of tolerability and reasonableness, including a balanced view of risks were mentioned as a priority by all of those responding to this request, with two IRPA Societies noting that a holistic approach to optimisation was an important topic missed off the priority list. There is a challenge to elaborate practical guidance adapted to specific exposure situations which must incorporate the ethical values.

A Benchmark for Comparing Radiation-related Cancer Risk among Countries: Baseline Cancer Rates of Incidence and Mortality

Jun HIROUCHI (Japan Atomic Energy Agency)*, Ikuo KUJIRAOKA (JAEA, Japan), Shogo TAKAHARA (JAEA, Japan), Momo TAKADA (AIST), Michiaki KAI (NBU), Therry SCHNEIDER (CEPN)

Abstract–When considering the basis for radiation protection criteria based on calculated risk of radiation induced cancer, statistical benchmark data are necessary. So far, the risk assessment study of the UK Royal Society was used as a benchmark statistic. In this study, we focus on the baseline cancer rates of incidence and mortality and compare with radiation-related cancer risk. The risk models that can be expressed by Excess Relative Risk (ERR) and Excess Absolute Risk (EAR) were developed based on the epidemiological study on radiation risk to calculate the radiation risk for the population with a different cancer baseline. From comparison purposes, the baselines for cancer incidence and mortality can be used as benchmarks. In this presentation, lifetime mortality and incidence risks and Disability-Adjusted Life Years (DALYs) were first calculated using cancer incidence and mortality data in different countries (including three Asian, two Oceania, eight Eastern European, four Northern European, five Southern European, seven Western European, two North American, and six South American) and were compared among the countries. In addition, the indicators for radiation exposure were also calculated and were compared among the countries. The distribution of the risk on baselines among countries will be able to be used as a reference to discuss risk tolerability. These indicators are used in various fields such as chemical, environment, and public health. Especially, the DALYs are aggregate indicators that can consider both mortality and incidence, and has been used recently in various fields.

The indicators for baselines were calculated using the 2010 dataset on baseline for cancer mortality and incidence obtained from the WHO database. In addition, the indicators for radiation exposure were also calculated. The exposure situation was assumed to be occupational exposure, 20 mSv y^{-1} between the ages of 18 and 65 and a total dose of approximately 1 Sv. The risk models that can be expressed by Excess Relative Risk (ERR) and Excess Absolute Risk (EAR) were based on the ICRP Pub.103.

For all solid cancer, the lifetime mortality risk, lifetime incidence risk, and DALYs for baseline ranged approximately 0.12–0.30, 0.22–0.54, and 0.010–0.044 y, respectively. The ratio of radiation risk to baseline risk in male and female were approximately 0.040–0.15 and 0.11–0.24, respectively. The excess increases due to the radiation for DALYs and lifetime incidence risk were almost similar to each other and were larger than that for lifetime mortality risk. Finally, the lifetime mortality risk, lifetime incidence risk, and DALYs for the sum of baseline and radiation risks ranged approximately 0.14–0.31, 0.24–0.58, and 0.012–0.049 y, respectively.

Our study suggested the benchmark for comparing radiation cancer risks should be the health risk based on baseline cancer rates. In particular, DALYs are unique and common risk indicators that can measure both mortality and incidence.

The Work of ICRP Task Group 121 – the Effects of Preconceptional and Intrauterine Exposures

Richard WAKEFORD (The University of Manchester)*

Abstract–The health effects resulting from exposure to ionizing radiation of parents before the conception of a child and from exposure of the embryo/fetus between conception and birth are components of the ICRP system of radiological protection. The exposure of the germ cells of parents poses a risk of hereditary effects in subsequently conceived offspring and their descendants. Exposure in utero poses risks of stochastic effects (cancers in the exposed individual and hereditary disease in the individual's descendants) that also arise following exposures after birth, although potentially with different levels of risks, but the teratogenic (developmental) effects of intrauterine exposure are also a specific consideration. Preconceptional and intrauterine exposures are addressed in the 2007 Recommendations of the ICRP, but ICRP Task Group 121 is examining how evidence that has become available over the past two decades or so may affect risk estimates, particularly in preparation for the next set of ICRP recommendations. Risks of hereditary effects following exposure of parental gonads have not been conclusively identified in epidemiological studies of humans, so ICRP risk estimates are currently based on the results of large experimental studies of laboratory animals, mainly mice, together with an incomplete knowledge of human genetics. This has led to complex calculations of estimates of the risks of hereditary effects for the purposes of radiological protection that were primarily constructed by the late Krishnaswami Sankaranarayanan and his colleagues in a series of journal papers and in the UNSCEAR 2001 Report. Members of TG121 are assessing this technical basis of the 2007 Recommendations together with more recent evidence to evaluate whether changes to hereditary risk estimates are required, and if so, their magnitude. The impact of preconceptional exposure upon multifactorial diseases, especially those of old age, is a particular matter under consideration. Intrauterine exposure also presents challenges to assessing risks. In 2003, ICRP Publication 90 was published, which reviewed the risks from exposure to radiation in utero, and this review fed into the 2007 Recommendations. Epidemiological studies of childhood cancer following fetal exposure to radiation from medical diagnostic examinations was one of the first pieces of evidence that low doses could increase the risk of cancer, but the interpretation of these findings is controversial, even today. Severe mental retardation among Japanese atomic bomb survivors who were exposed in utero to moderate and high doses during the development of the central nervous system was a clear excess risk found in the early studies of the survivors. One associated question is whether there is an effect of lower-level exposures upon IQ and if so whether there is a threshold for such an effect. Studies continue of health effects among the atomic bomb survivors exposed in utero, and evidence will accumulate as the cohort ages, but evidence now exists for an excess risk of solid cancer in adult life, at least, for women. This is a glimpse of the issues that are being addressed by ICRP Task Group 121.

A Multidisciplinary Challenge to Assess the Next-generation Risks of Low-dose-rate Long-term Gamma-ray Exposure by Whole-genome Sequencing in the Mouse Model

Yoichi GONDO (Tokai University School of Medicine)*, Arikuni UCHIMURA (RERF), Manabu YONEYA (IES), Satoshi TANAKA (IES), Jun-Ichiro KOMURA (IES), Minoru KIMURA (Tokai Univ), Mizuki OHNO (Kyushu Univ), Hiroshi TOKI (Osaka Univ), Masako BANDO (Kyoto Univ), Yuichi TSUNOYAMA (Kyoto Univ), Yoshihisa MATSUMOTO (TITEC), Hisaji MAKI (NAIST), Yoshiya SHIMADA (IES)

Abstract–Applying the expanded TRIO analysis (Gondo, RPD 198: 1137-1142, 2022), we conducted multigenerational accumulations of mutations in the mouse to assess the effects of low-dose-rate radiations on the next generation.

A pair of C57BL/6JJcl inbred mice (G0) produced four pair of G1 mice. Each pair was exposed to either 0, 0.05, 1, or 20 mGy/day at Institute of Environmental Sciences (IES). Exposures were started at the time of G1 mating from generation to generation. We independently conducted 0.15 mGy/day exposure at Tokai University. After mutations were accumulated, the descendants' genomic DNAs were subjected to whole-genome sequencing (WGS). High-throughput bioinformatics pipelines (Uchimura et al. This session, ICRP2023) extracted de novo mutations. This presentation primarily focuses on the autosomal single base substitutions (SBSs).

We have successfully obtained four G4 mice from each exposed pedigree of 0, 0.05, and 1 mGy/day exposure at IES (IES1 mice) and nine G4 mice from each exposed pedigree of 0 and 0.15 mGy/day exposure at Tokai University (TOKAI mice). In IES1 mice, we have identified 25.0 (SE=0.86), 24.8 (SE=0.71), and 25.0 (SE=0.86) SBSs/mouse/generation with 0, 0.05, and 1 mGy/day exposures, respectively. In TOKAI mice, 24.6 (SE=1.20) and 22.5 (SE=0.60) SBSs/mice/generation were detected with 0 and 0.15 mGy/day exposures, respectively. No significant differences were found in these data from the IES1 and TOKAI mice. Contrarily, the 20 mGy/day exposure at IES showed a direct radiation effect on the G2 females that were found to be infertile. We, therefore, mated the G2 males from 20 mGy/day exposed pedigree to the unexposed G2 females. Six G3 mice from the alternative G2 mating and six unexposed G3 mice, a total of 12 IES2 mice, were then subjected to WGS. In the G3 mice (IES2), we have found 24.6 (SE=0.78) and 32.9 (SE=1.91) SBSs/mouse/generation with 0 and 20 mGy/day exposures, respectively. The detected number of SBSs in the 20 mGy/day exposed mice was significantly increased to that in the unexposed control mice ($p<0.005$), which is the lowest dose rate ever detected radiation-induced germline SBSs.

In this study, we have detected a total of 4,058 de novo SBSs encompassing X chromosomes from 42 mice in two years. It demonstrates the method is efficient to assess the radiation effects on the next generation, particularly, of the low-dose-rate longtime exposure. It now becomes feasible and realistic to conduct experimental studies and discuss the low-dose-rate longtime exposure effects on the next generation based on large-scale datasets under various conditions by setting appropriate negative controls. Toki et al. and Bando et al. also report further statistical analyses, mathematical modeling, and comparisons to the historical SLT analysis (Russell and Kelly, PNAS 79: 539-541, 1982) in this ICRP2023 conference.

History and Future Prospects of RERF Studies on Offspring of Atomic Bomb Survivors

Asao NODA (Radiation Effects Research Foundation)

Abstract–Since 1948, RERF has investigated the genetic effects of atomic bomb radiation exposure through a pregnant women-based, 77,000-person survey of offspring (F1) birth, health, and death. The early focus of the F1 study was on potential effects of parental germ cell exposure on genetic changes in offspring. An initial study on F1 birth and neonatal development has subsequently expanded into studies of chromosomal mutations, serum protein mutations, and multifactorial diseases, using the latest technology of each era. No obvious changes have been observed to date. Parental germ cells with large genomic deletions or structural mutations are thought to be eliminated during reproductive processes, prior to the birth of F1 offspring. Moreover, parental genomic or epigenomic mutations need to exhibit dominant or haploinsufficient traits to manifest as F1 phenotypes. On the other hand, it is not easy to evaluate the biological effects of mutations in non-coding regions of the genome. With the advent of affordable whole genome sequencing (WGS), RERF is planning a large-scale WGS with trios of A-bomb survivors and their children, using blood samples collected since 1985. Genetic data will be analyzed along with radiation dose, F1 health status, and lifestyle information. Genetic research on A-bomb survivors is carried out with the utmost respect for the survivors, and would not be possible without the understanding and support of the study participants and surrounding citizens. Over the past eight years, RERF has held ongoing discussions with survivors and offspring including stakeholder meetings and workshops to discuss the ethics of genetic research. In this session, I will discuss the status of the genetic studies on the offspring of atomic bomb survivors.

Whole Genome Sequencing Analysis for Understanding Next Generation Effects of Radiation Exposure

Arikuni UCHIMURA (Radiation Effects Research Foundation)*

Abstract–Radiation induces genomic DNA damages and increases the number of de novo mutations. Recent technological advances in next-generation sequencing have enabled us to directly analyze de novo mutations at the whole-genome level. To date, we have been working to develop methodologies to analyze genome-wide mutations using whole genome sequencing. In the first phase, we have built an original genomic data analysis pipeline, including the establishment of Effective Whole-genome Coverage regions (EWC regions), which enables us to detect base substitutions and insertion-deletions with high accuracy and great ease. This allowed us to determine the rate of spontaneous de novo germline mutations in laboratory mice (Uchimura et al, Genome Research, 2015) and to show that radiation exposure to mouse spermatogonia and oocytes increases small-size insertion-deletions and multisite mutations in their offspring in both cases (Satoh et al, Scientific Reports, 2020). In the next step, we developed another analysis pipeline to efficiently detect de novo structural variants by using a combination of multiple mutation detection software. This revealed that in mouse hematopoietic stem cells (HSCs), radiation exposure increases de novo structural variants in addition to increasing base substitutions, small-size insertion-deletions, and multisite mutations (Matsuda et al, PNAS, 2023). Furthermore, by utilizing the allele frequencies of individual mosaic mutations, which are present at low frequencies in tissues, we have successfully developed a new methodology that allows us to mathematically reconstruct detailed cell lineages in early embryonic stages (Uchimura et al, Genome Research, 2022). In this talk, I will give an overview of our mutation analysis system and the results of these studies. I will also introduce our future plan for "whole genome sequencing of atomic bomb survivors and their children" using our mutation analysis system. I would like to discuss what kind of analysis, including whole genome sequencing, will be needed in the future to understand the whole picture of the effects of radiation exposure on offspring.

Medical System for Radiation Emergency in Japan

Takako TOMINAGA (National Institute for Quantum Science and Technology)*

Abstract–In response to the accident at TEPCO Fukushima NPP in 2011, there was a shortage of hospitals and personnel capable of accepting contaminated patients under the radiation emergency medical system. This is because, at the beginning of the nuclear disaster, it was difficult to accept contaminated patients at secondary level radiation emergency hospital in Fukushima Prefecture, and primary level radiation emergency hospitals around the Fukushima Daiichi NPP were evacuated.

Since then, radiation emergency medical system in Japan has been strengthened, enhanced, and expanded. The current radiation emergency medical system is in place in 24 prefectures where nuclear facilities are located. Each prefecture designates nuclear emergency medical cooperative institutions, and nuclear emergency core hospitals. Nuclear emergency medical cooperative institutions cooperate with prefectural and nuclear emergency core hospitals regarding nuclear disaster countermeasures. Nuclear emergency core hospitals provide medical care to the patients who exposed to radiation and/or contaminated with radionuclide. A nuclear disaster medical dispatching team was also in place. The government has designated the Advanced Radiation Emergency Medical Support Center and Nuclear Emergency Medical Support Center, and the NIRS-QST has also been designated as the core advanced radiation emergency medicine support center, which plays central role in the radiation emergency medical system. Training and education in nuclear disasters and radiation emergency medicine are systematically carried out for medical personnel in these hospitals. In this presentation, we introduce the radiation emergency medical system in Japan.

The work of ICRP TG120 on Radiation Emergencies and Malicious Events

Anne NISBET (UK Health Security Agency, Chair ICRP TG120)*

Abstract–In 2005, ICRP Publication 96 set out guidelines for protecting people against radiation exposure in the event of a radiological attack. Since then, ICRP has updated its fundamental recommendations in Publication 103 (2007) and also produced Publication 146 (2020) giving advice on protecting people and the environment in the event of a large nuclear accident. This leaves an important gap in the advice offered by ICRP for radiological emergencies that are not large nuclear accidents. Furthermore, some of the basic concepts/approaches described in Publication 96 have been superseded by the 2007 recommendations, so the advice currently offered by ICRP for malicious events is not as consistent or comprehensive as it should be.

A Task Group (TG120) was established by ICRP in 2021 with a mandate to develop ICRP recommendations for radiological protection for a wide range of radiation emergencies and malicious events, including a nuclear detonation. These recommendations will complement those given in Publication 146 for large nuclear accidents. To date, TG120 has critically reviewed the content of Publication 96 to identify out of date and redundant material as well as emerging gaps. The TG has also documented a series of case studies encompassing previous radiation emergencies such as transport accidents, fires and other events at sites holding radioactive materials, the inadvertent damage to sealed sources, and the targeted poisoning of an individual. For all scenarios, a graded approach to protection is being taken, with the aim of making the advice as generally applicable as possible, accepting that specific guidance may be required for some distinctive aspects. For example, special consideration is being given to radiological protection advice for emergency responders, particularly in relation to malicious events. Furthermore, differences in recommendations for public protection between accidents and malicious events will be highlighted.

The content of the TG report will include reference to latest advances in medical triage and management, radiological triage, treatment of internal contamination, and urgent protective actions relevant to the early response phase. Later response actions will include decontamination, waste management, and foodstuff management. Cross cutting issues such as protection of the environment, stakeholder engagement and mental health and psychosocial impact will be discussed along the emergency timeline.

As a result of the conflict in Ukraine, the TG has already published guidance for public protection in case of a nuclear detonation. This includes advice for the first 10 minutes, first 24 hours and next 48 hours. It also describes preparedness and responding to alerts. The importance of public messaging, particularly in the context of a nuclear detonation has prompted the TG to recruit mentees with backgrounds in social science and risk communication. Going forward, the TG will provide guidelines and best practices on when, how and what to communicate; including how to counter misinformation. In addition, templates for timely social media messaging following a radiation emergency or malicious event will be developed.

This paper provides an overview of the TG's work to date, highlighting areas where clarification and modification to previous ICRP recommendations may be necessary.

New WHO Policy Advice on National Stockpiles for Radiological and Nuclear Emergencies

Zhanat CARR (World Health Organization)*, N. DAINIAK, C. Li, M. PORT, A. DICARLO, M. BENDERITTER, C. HERMANN, M. AKASHI, A. KUMAGAI, A. BUSHMANOV

Abstract–Certain types of radiological and nuclear emergencies may result in severe health consequences either dues to over-exposure to radiation, or due to the interventions implemented during the response. It is important that countries are prepared to respond rapidly to such threats, however many countries lack the essential elements of preparedness for radiation emergencies, according to annual reporting to the World Health Organization (WHO) Secretariat under the requirements of the International Health Regulations. As global leader on health, with the authority and responsibility to assist in health emergencies, WHO provides advice and guidance to countries on public health preparedness and response to radiation emergencies. In health emergencies WHO may assist in procuring or sharing medical supplies among countries. In January 2023, WHO published a new policy advice on national stockpiles for radiological and nuclear emergencies and their appropriate management. The publication supersedes the 2007 WHO report on the development of national stockpiles for radiation emergencies. It includes updated information on the stockpile formulary based on the recent developments in radiation emergency medicine and new experiences on providing access to medicines during health emergencies. The report was developed during 2021-2022 by the working group of the WHO Radiation Emergency Medical Assistance and Response Network (REMPAN) and published in January 2023.

Potential scenarios considered in the publication include radiological or nuclear emergencies at nuclear power plants, medical or research facilities, or accidents during transport of radioactive materials, as well malicious events. The report provides advice for acquisition of specific drugs preventing or reducing uptake of radionuclides or increase their elimination from the human body. Main elements required for developing, maintaining and managing the national stockpiles of specific medical supplies required for radiological and nuclear emergencies are discussed in this report. Training and education for responsible staff, communication and coordination between local, national and international response are essential for ensuring an efficient use of stockpiles in response to radiation emergencies. The report looks at the role of national health authorities in stockpile development as well as the role of WHO.

In addition, this report includes a brief review of selected emerging technologies and drug formulations, including potential repurposing of products previously approved for other indications. Finally, the publication provides examples of practices in establishing and managing a national stockpile in selected countries, namely Argentina, Brazil, France, Germany, Japan, Republic of Korea, Russian Federation and USA.

Communicating Radiation Emergencies on Social Media

Maren GRUß (ICRP & Federal Office for Radiation Protection)*, David SIBENALER (ARPANSA)

Abstract–In a radiation emergency or malicious event, it is vital that those responsible for managing the emergency inform the population about potential risks from the radionuclides released and about the protective actions that can be taken to reduce those risks. Communicating potentially life-saving information before, during, and after a radiation emergency or malicious event is a significant challenge for communicators. Extensive research on crisis communication over the years has developed a series of recommendations for communication during a wide range of emergencies. However, less well researched is the impact of more recent changes in the types of media used and how this may affect for example, the behavior of the public (Newman et al. 2023), and any subsequent crisis communication. The transformation of the social media landscape over the past 15 years is the best example on which to observe these developments and provide insight into how communication about radiation emergencies can keep pace with Twitter, WhatsApp and TikTok.

Specific research on the use of social media in radiation emergencies has been limited. This is partly because many of the previous radiation emergencies occurred when social media was not as prolific as it is today (Drescher et al. 2021). A systematic review (Gauntlett et al. 2019) of how radiation emergencies were communicated to the public posed this question: “To what extent could social media be used to provide clear and reliable information to the public before, during, and after a radiological incident?” Facing challenges such as the increased speed of information dissemination, the spread of misinformation, or the sheer volume of potentially conflicting information online, this question is not easy to answer.

Drawing on different case studies of radiation emergencies (e.g. Fukushima Daiichi accident) and other health crises (e.g. Covid-19 pandemic), this presentation will provide arguments about the importance of communicators, in not only understanding their target audience but also in being familiar with social media, and adapting their communication strategies accordingly. Furthermore, the presentation will identify gaps in knowledge, and future communication opportunities. It will also inform work of ICRP Task Group 120 on how to best to use social media during radiation emergencies and malicious events.

A Survey of Image Guided Radiation Therapy Practices around the Globe

Colin MARTIN (University of Galsgow)*

Abstract–The use of image guided radiation therapy (IGRT) has increased in recent decades to take advantage of improvements in shaping radiation fields from linear accelerators to tumour target volumes. Imaging may be carried out at each fraction and since this exposes normal tissues to additional radiation, there is concern about extra dose that this gives to normal tissues. ICRP set up Task Group 116 (TG116) to prepare guidance on radiological protection aspects of IGRT in 2020. Since information available about use of IGRT around the world is limited, TG116 set up a survey through the ICRP mentorship programme to collect more information. The survey took the form of a questionnaire on imaging practices including 130 items of data. Mentees contacted radiotherapy centres within their countries and the survey was conducted on-line using Survey Monkey®. Data were collected for 3½ months starting in late summer 2020. 97 radiotherapy centres for which there were complete sets of data were included in the final analysis. These were distributed over nine countries in six continents. Close liaison between mentees and radiotherapy centres allowed clarification of issues in interpretation of data. Although in higher income countries the numbers of centres in the survey only represented a few percent of the total, over 20% of radiotherapy centres took part in five middle- and lower-income countries. The survey provided a snapshot of practices that could inform TG116 during preparation of the report. All centres used CT for treatment planning with some involving magnetic resonance imaging or positron emission tomography in the planning process. Results for individual countries were compared against the human development index (HDI) value, that combines indices of health, education and income, with countries surveyed having values between 0.7 (low) and 0.95 (high). kV cone beam CT (CBCT) was used during treatment delivery by all centres in countries with HDIs over 0.8, but countries with lower HDIs had fewer kV CBCT facilities. Most centres had one linac with kV imaging, apart from the country with an HDI of 0.7, which had only two linacs out of 17 with kV CBCT. Imaging was generally carried out more frequently in countries with higher HDI values, and followed similar patterns for most types of treatment. Centres in the country that relied on MV imaging generally only used this once per week or once per course of treatment. Imaging dose was measured as part of quality control in all centres in three countries, but only 30%-60% of centres in five countries. Less effort has been put into optimisation of radiological protection in imaging for radiotherapy than for diagnosis. Most centres used imaging protocols supplied by the vendor with limited optimisation, and although in three countries 50% of centres recorded a measure of patient dose, less than 15% recorded doses in the remainder. Thus, information on patient doses from imaging in radiotherapy centres around the world is limited and needs to be expanded, in order to order to start the process of optimisation.

Fit for Purpose: Dose Optimization in Radiotherapy Imaging in a Large Organization

Tomas KRON (Peter MacCallum Cancer Centre)*, Deepak BASAULA (Peter MacCalum Cancer Centre), Deloar HOSSAIN (Peter MacCalum Cancer Centre)

Abstract–Radiotherapy relies on imaging to deliver radiation to the correct target while minimizing the dose to healthy surrounding tissues. As such it is no surprise that imaging is an essential and growing part of modern radiotherapy. Significantly, imaging is not only used for diagnostics but imaging for treatment planning and image guidance during treatment delivery are imaging procedures solely performed for radiotherapy purposes. The aim of this presentation is to review imaging practice in radiotherapy and attempts at dose optimization using examples from Peter MacCallum Cancer Centre, a large public radiotherapy provider in Australia.

The most important imaging modality for radiotherapy treatment planning is Computerized Tomography (CT) due to its volumetric nature, spatial resolution, lack of distortion and the possibility to use CT information for dose calculation. CT scanners and imaging procedures in radiotherapy often differ from the ones used in diagnostic radiology. Radiotherapy CT scanners typically feature a wide bore to accommodate different patient set-ups, external lasers for positioning and a flat couch top that mimics treatment units. Interestingly, it was just these features which resulted in the largest number of incidences in an assessment across our seven CT scanners. Breathing gated 4DCT, which is routinely used for many thoracic and abdominal cancers, acquires 10 CT images in different phases of the breathing cycle which could result in a significantly higher dose. In an audit at our institution, we established that most 4DCT was conducted with approximately twice the dose of a conventional scan and work is in progress to develop Dose Reference Levels (DRLs) for these scans.

Apart from stereotactic radiotherapy, most radiotherapy is delivered in several fractions ranging from 5 to over 30 daily deliveries. As image guidance is required for each fraction, dose from imaging can be substantial in particular as many cases require volumetric imaging to verify target position in three dimensions. Cone Beam CT is the most common imaging modality and a multidisciplinary group was established at our institution to optimize CBCT protocols and standardize them across our five campuses. Images with four different combinations of kVp and mA were acquired for five standard protocols (head, thorax, spotlight, pelvis and large pelvis) using an anthropomorphic phantom. Image quality in relation to the set-up task was assessed by radiation therapists and dose measured. The optimized protocols were found to reduce dose from the factory setting by a factor of 1.4 to 2.7.

In the fast-developing field of radiotherapy other imaging modalities are becoming available for treatment planning and delivery verification. Of particular interest in our institution is optical surface guidance for patient set up and monitoring, which can complement conventional imaging without adding dose to the patient. In any case, optimization of imaging in radiotherapy is a multidisciplinary task with aim to make imaging ‘fit for purpose’ and raise awareness about radiation dose not only for practitioners but also patients and manufacturers.

Development of a Methodology for Measurement of Dose for Cone Beam CT Scans in Radiotherapy

Mario DJUKELIC (Sir Charles Gairdner Hospital)*

Abstract–Image guided radiotherapy (IGRT) has become an invaluable tool in cancer treatment over the last few decades. Imaging modalities such as on-board kilovoltage cone-beam computed tomography (kV CBCT) on a linear accelerator (linac) are utilised daily to verify positioning in a multi-week fractionation schedule of cancer patient undergoing treatment. Well-established guidelines such as American Association of Physicists in Medicine Task Group 142 recommend monitoring kV CBCT imaging doses in IGRT on an annual basis. The International Commission on Radiological Protection set up a Task Group 116 (ICRP TG-116) to prepare guidance on radiological protection aspects of IGRT in 2020. In the same year, ICRP TG-116 conducted an international survey through the ICRP mentorship programme. The survey showed, amongst others, that imaging dose optimisation in IGRT is limited across many radiotherapy centres in the world. In 2022, ICRP TG-116 established a dosimetry group via the ICRP mentorship programme that explores an alternative and a more accessible method to assess kV CBCT imaging dose that can be used to initiate an imaging dose optimisation process. Conventionally, the computer tomography dose index (CTDI) is a well-established dose metric to assess radiation dose in fan-beam CT. This involves utilising 100mm pencil type ionisation chambers and cylindrical CTDI phantoms made from polymethyl methacrylate (PMMA) which are not necessarily available in radiotherapy centres. The proposed ‘alternative setup’ is essentially following a similar methodology as the ‘conventional setup’ but using wide cone-beam to determine ‘a weighted dose index for cone-beam CT’ (weighted dose index). Instead of using a 100mm ionisation chamber and a cylindrical PMMA phantom, the alternative setup is using a 0.6cc Farmer type ionisation chamber and a 30x30x30cm cubically shaped phantom comprised of slabs of water equivalent material typically used in radiotherapy centres such as Solid Water® or PTW RW3, or PMMA. The weighted dose index determined from the alternative setup are compared with the weighted dose index determined from the conventional cylindrical CTDI phantoms. The measurements are obtained from the network of ICRP TG-116 mentees across the world. All mentees use a standardised measurement protocol that includes specific imaging protocol technique factors for various linac manufacturer and models. Preliminary results show that the weighted dose index from the alternative setup is 9% higher and 9% lower than the weighted dose index from the conventional setup for PTW RW3 and PMMA cubical phantoms, respectively. The results indicate that the alternative setup using more accessible radiotherapy equipment such as 0.6cc Farmer type ionisation chamber and slabs of water equivalent phantom and PMMA is a viable alternative to quantify kV CBCT radiation dose from linac based IGRT that can be used for dose tracking and optimisation processes. This will allow most radiotherapy centres all over the world to engage in meaningful dose measurement and optimisation for CBCT.

Image-guided Heavy Ion Therapy

Shinichiro MORI (National Institutes for Quantum Science and Technology)*

Abstract–Ensuring patient positional accuracy, especially when treating moving targets, presents a significant challenge in particle beam therapy. In heavy ion therapy, the distinct physical and biological properties of heavy charged particle beams theoretically allow for a reduced number of treatment fractions through dose escalation, often termed hypo-fractionated treatment. Consequently, any deviation from the target or any inadvertent dosing to adjacent healthy structures can severely compromise treatment precision.

Motions of particular concern in particle beam treatments are those that exceed roughly 0.5 cm and occur within an approximate 4-minute window (intra-fractional) or those that alter patient geometry on a daily basis (inter-fractional). Imaging is pivotal in addressing both intra- and inter-fractional variations. Before treatment, it's essential to assess the extent of positional deviations and create patient-specific motion models. During treatment, monitoring these positional changes and implementing appropriate mitigation strategies is crucial. To correlate images of the same patient captured at different times, image registration is indispensable. However, this brings its own set of challenges and potential ambiguities. It's vital that patient-specific positional deviations, along with corresponding mitigation strategies, are factored into treatment planning.

In this presentation, I aim to underscore the significance of "imaging" and "image guidance" in cutting-edge particle beam therapy, highlighting the integration of real-time imaging within heavy ion therapy.

Unique Aspects of Justification in Medicine: An Ethical Way Forward for the Radiological Protection Community

Sergio SALERNO (University of Palermo)*, Kimberly APPLEGATE (University of Kentucky College of Medicine (retired))

Abstract–The Task Group 124 has begun a review of the fundamental principle of justification, first introduced in 1977 with Publication 26. For medical patients, further guidance was provided in 1996 in Publication 73. This document provides guidance of three levels for justification but also two levels of optimization and introduces the diagnostic reference level (DRL). The three levels of justification move from the most general definition of doing more good than harm (level one), to the second level of using an evidence-based referral guideline to select an imaging procedure, to the third level of decision-making at an individual level. This last level often requires the radiological protection professional to use both their clinical experience and their ethical knowledge as they apply it to a shared decision-making process with the patient, family, and clinical team. In the large majority of patient scenarios, there will be pre-established evidence-based protocols (level 2). However, there will be some that require modification or the creation of individualized imaging procedures (level 3) in medicine. Examples include interventional procedures, radiation therapy, and those with rare diseases or radiosensitive populations. Further clarification of the evolution of ethical aspects and the importance of education and training will be provided in TG109 (ethics in radiological protection for medical diagnosis and treatment). Finally, the presentation of justification in medicine will include ways to define and measure patient outcomes and for the basis of technology assessment.

All-hazard Approach to Preparedness and Response for Complex Disasters

Terumasa NIIOKA (Nuclear Disaster Management Bureau, Cabinet Office, Government of Japan)*

Abstract–Due to geographical and topographical conditions, Japan is prone to natural disasters such as earthquake, typhoon, heavy rainfall and heavy snowfall. Nuclear emergencies could take a form of complex disaster as demonstrated in the accident of Fukushima Daiichi Nuclear Power Station, and it is necessary to take an all-hazard approach in preparedness and response against them. Under the Act on Special Measures Concerning Nuclear Emergency Preparedness, the NRA Guide for Emergency Preparedness and Response (NRA EPR Guide) has been established to ensure the smooth implementation of nuclear emergency response measures. At the same time, the Basic Disaster Management Plan is formulated based on the Basic Act on Disaster Management which stipulates "The safety of human life is the number one priority. In case the direct risk to human life from a natural disaster is exceptionally high, actions against it should be taken first, in principle, and once escaping from the life-threatening situation, nuclear emergency evacuation is started." Based on these guides and principles, the national and local governments are required to elaborate emergency plans taking into consideration the regional circumstances. In this presentation, some examples of the regional emergency plan are provided, and current challenges will be discussed from the viewpoint of the principle of justification.

Justification : Views from IRPA

Bernard LE GUEN (International Radiation Protection Association (IRPA))*, Claire-Louise CHAPPLE (IRPA)

Abstract–The International Radiation Protection Association (IRPA) has set up a Task Group to inform Associate Societies (AS) about the review of the System by ICRP this initiative, encouraging them to organise feedback through IRPA and independently, and consolidating views reflecting areas of broad consensus and the spectrum of views of the profession. The various sets of feedback provide a good overview of the main issues for radiation protection professionals, and an indication of direction for the ICRP in addressing these, including application of the principle of justification as a priority area.

From the feedback received, justification was recognised to be an important issue, that is currently poorly understood or applied in some quarters. Specific comments were made concerning justification according to exposure situation and a justification system based on ethical values. It was also recognised that there are situations where radiation exposure is a major concern, but judgements of justification are not straightforward, for example non-medical human imaging or remedial actions for existing exposure situations.

Medical exposure is a particular concern. There is a considerable increase of the medical radiation dose burden to the world population, with 4 billion X-ray examinations are performed annually worldwide. Even though we have had the principle of justification for about 40 years, every study on the frequency of unjustified examinations in clinical practice finds alarmingly high values. Radiation protection, regulatory and medical professionals have a role to play dealing with the problems involved, in the interests of all the stakeholders and especially patients.

IAEA Activities in Relation to Justification of Medical Exposure

Ola HOLMBERG (IAEA)*

Abstract–With justification being one of the three fundamental principles of radiation protection overall, and one of the only two principles to use for the radiation protection of patients, together with optimization of protection and safety to minimize unnecessary and unintended radiation exposure of patients, the International Atomic Energy Agency (IAEA) has long pursued activities to strengthen justification of medical exposure. This has been done through Consultancies (for expert opinions); Technical Meetings (for Member States' and International Organizations' advice); International Conferences (for review of current level of knowledge and dissemination); Publication of Safety Standards (for requirements and harmonization of approach); Publication and issuing of guidance, peer-reviewed publications; promotional material and calls-for-action (for mobilizing international efforts and stimulate implementation).

Already in 2008, the IAEA led the 3A's campaign: "3 A's: awareness, appropriateness and audit" on strengthening justification. The 3A's campaign led to e.g., the Nordic radiation regulatory authorities issuing a statement to support this concept. The following year, an international workshop was held together with EC on "Justification of Medical Exposure in Diagnostic Imaging". A series of technical meetings explored the issue in theory and practice, and it was the first action highlighted in the Bonn Call for Action, which was pursued, as the majority of activities on justification, together with the WHO. A number of peer-reviewed scientific papers were published on the topic with involvement of the IAEA, while the emphasis was shifted more to implementation from 2017 onwards. Looking forward, the issue of impact of recurrent imaging on justification is being explored.

Development and Clinical Application of Targeted Alpha Therapy using Astatine (At-211)

Tadashi WATABE (Osaka University)*

Abstract–Targeted alpha therapy (TAT) is gaining attention for its high therapeutic efficacy compared to conventional radionuclide therapy using beta emitters. However, the history of clinical use of alpha emitters is still relatively short, and it is necessary to proceed with clinical applications while considering sufficient radiological protection. Recently, astatine (At-211) has been garnering attention as an alpha-emitting radionuclide, as it can be produced by irradiating natural bismuth targets with alpha beams using a 30 MeV cyclotron. In Japan, we are conducting an investigator-initiated clinical trial using [At-211]NaAt as an iodine analogue for patients with refractory thyroid cancer. This Phase-1 investigator-initiated clinical trial represents the first use of At-211 for injection in patients. Compared to beta emitters such as I-131 or Lu-177, the administration dose (radioactivity) is small for alpha emitters. Furthermore, alpha emitters typically emit minimal gamma rays, resulting in minimal radiation exposure to the surrounding individuals. The Scientific Research Group of the Ministry of Health, Labor, and Welfare, led by Prof. Makoto Hosono (Kindai University), has already conducted investigations and demonstrated that radiation exposure remains far below the limits for the general public and caregivers, even if the patient leaves the radiation controlled area immediately after the administration of [At-211]NaAt (Watabe T, et al. Ann Nucl Med. 2021). Therefore, hospitalization in an isolation ward within the RI controlled area is not required for targeted alpha therapy using [At-211]NaAt. In this presentation, I would like to introduce the current state of clinical TAT and radiation protection in the clinical trial using [At-211]NaAt.

Contribution of QST to Radiation Protection in Ion Beam Radiotherapy after Publication of ICRP127

Shunsuke YONAI (National Institutes for Quantum Science and Technology)*

Abstract–Ion beam radiotherapy is an external beam radiation therapy that has the advantage that the physical properties of charged particles allow for high dose concentration on the target volume and reduced dose to surrounding normal tissues. The International Commission on Radiological Protection (ICRP) published ICRP Publication 127: Radiological Protection in Ion Beam Radiotherapy in 2014 [1], in which summarized and made recommendations on radiation protection considerations in ion beam radiotherapy (IBRT). This publication addresses the radiation safety management for the IBRT facility and preventing accidental exposures of patients from IBRT as well as the three categories of exposure: medical exposure, occupational exposure, and public exposure. In 2023, IBRT is still one of the most remarkable treatment modalities for solid tumors, and approximately 40 IBRT facilities are currently under construction. The number of the IBRT facilities in operation has doubled and the cumulative number of patients has nearly tripled since 2014, according to the PTCOG website [2].

A major change since 2014 is the significant increase in the number of irradiation system using a scanning beam method, especially in carbon ion radiotherapy (CIRT). It was well known that the use of the scanning method theoretically makes it possible to increase the efficiency of the beam to reach the patient, resulting in many advantages for radiation protection, such as less secondary neutron production and less activation material. At the time, however, there was little data on them, and it was difficult to discuss them quantitatively. In addition, because IBRT is a relatively new treatment, there were no published studies that assessed the risk of secondary cancers based on epidemiological data of patients who received IBRT.

The National Institutes for Quantum Science and Technology (QST) has continuously investigated radiation protection in IBRT mainly in CIRT. In this presentation, our research results on the radiation protection in IBRT after the publication of ICRP127 will be presented, with a focus on medical exposure in CIRT. In conclusion, it can be suggested that the "Conclusions and Recommendations" shown in ICRP127 is still valid today.

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High-resolution Analysis of the DNA Damage Pattern Following Heavy Ion Irradiation Using Electron Microscopy

Claudia E. RÜBE (Saarland University Medical Center, Radiation Oncology)*

Abstract–High linear energy transfer (LET) irradiation (IR) features a unique depth dose distribution and higher biological efficacy compared to low-LET IR. As a result, IR with heavy ions in clinical radiation oncology offers a promising therapy option for radiation-resistant and unfavorably located tumors. While low-LET IR induces single DNA lesions such as double-strand breaks (DSBs), the localized energy deposition of heavy ions along particle trajectories induces clustered DNA lesions that are difficult for the cell to repair. Using electron microscopy, we developed high-resolution techniques to image DNA damage in the context of chromatin at the nanometer scale and to analyze delayed repair of complex DNA damage.

RBE for Ion Beam and Targeted Alpha Therapy - from Medical Physics to Radiological Protection

Tatsuhiko SATO (Japan Atomic Energy Agency)*

Abstract–Precise evaluation of relative biological effectiveness (RBE) is essential in the treatment planning of ion beam and targeted alpha therapy. A fixed RBE value of 5 is recommended to use in the dosimetry of the targeted alpha therapy. On the other hand, various models such as microdosimetric kenetic model (MKM) and local effect model (LEM) have been proposed for evaluating the RBE of ion-beam therapy. They can consider the complicated dependences of RBE on energy and charge of ions as well as the absorbed dose.

Evaluation of RBE is also needed from the viewpoint of radiological protection. In 2021, the International Commission on Radiation Units and Measurements (ICRU) and ICRP jointly proposed the use of absorbed dose instead of equivalent dose for specifying dose limits to prevent tissue reactions. A similar proposal was also given in ICRP Publication 147. However, no recommendation has yet been provided as to how to derive RBE for the mixed radiation fields. To address these issues, ICRP recently launched a new task group for reviewing determinations of RBE for various endpoints including tissue reactions.

In this presentation, I will briefly review the recent studies on medical physics for evaluating RBE for ion-beam and targeted alpha therapy. Then, I will discuss the possibility of applying those studies to radiological protection research by introducing our recently developed model for evaluating the RBE for tissue reactions based on MKM.

Analysis of Solid Cancer Incidence in the LSS of Atomic Bomb Survivors: 1958-2009

Alina BRENNER (Radiation Effects Research Foundation (RERF))*, Dale PRESTON (Hirosoft International), Hiromi SUGIYAMA (RERF), John COLOGNE (RERF), Ritsu SAKATA (RERF), Eric GRANT (RERF), Mai UTADA (RERF), Elizabeth CAHOON (NCI), Richard SPOSTO (RERF), Kotaro OZASA (RERF), Kiyohiko MABUCHI (NCI)

Abstract–The most recent report concerning incidence of solid cancers in the Life Span Study (LSS) for 1958-2009 extended previous follow up by 11 years, adding nearly 6,000 new cases (72% exposed before age 20). The current update consists of a series of site-specific papers with common methods including improved individual radiation doses (DS02R1), updated estimates of migration rates, adjustment for smoking and other lifestyle factors, and exclusion of cancer cases identified solely at autopsy as these were found to introduce age-period-dose-related bias. As before, we characterized incidence rates and effects of radiation on these rates using Poisson regression method for grouped survival data. The general form of excess relative risk (ERR) model was as follows: $\lambda_0 \times (1 + ERR_{rad}) \times (1 + ERR_{smk})$, where λ_0 is the baseline rate of cancer for unexposed non-smokers that was allowed to depend on sex, city, attained age, year of birth, location at the time of the bombing, and other factors; ERRrad is the radiation excess relative risk; and ERRsmk is smoking excess relative risk. Cancer site-specific analyses allowed us to conduct more in-depth modeling of baseline rates with adjustment for relevant lifestyle factors. Parametric functions evaluated to characterize radiation dose response included linear, linear-quadratic, quadratic, and threshold. Greater emphasis was placed on assessing sex-specific dose response shape due to the unexpected finding of an upward curvature in all solid cancer dose response among males and lack thereof among females. To characterize dependence of radiation effects on attained age, age at exposure, and other factors, we applied multiplicative log-linear models. Independent of attained age and age at exposure, age at menarche emerged as a strong modifier of radiation effects on incidence of breast cancer. With additional data from survivors exposed during childhood, non-monotonic spline functions in age at exposure with a knot at menarche age provided better descriptions of breast and uterine corpus cancer data than the log-linear functions. These models predicted the highest radiation risks for exposures near menarche. Another site that supported a complex ERR model was lung cancer. The joint effects of radiation and smoking on rates of lung cancer were best described by a generalized multiplicative model under which ERRrad at a given dose and age was higher for low-to-moderate smokers than for heavy smokers, with little evidence of radiation-associated excess risk in heavy smokers. In summary, the large number of new cases and improved methods allowed us to estimate radiation risks for several cancer sites more accurately. As peak of radiation excess solid cancers is expected to occur in 2015-2020, being dominated by young survivors, it is important to continue LSS follow-up and reassess patterns of radiation risks.

A Short Review of Published Multi-Model-Inference Studies in Radiation Epidemiology and Some New Developments

Luana HAFNER (Swiss Federal Nuclear Safety Inspectorate (ENSI))*, Linda WALSH (University of Zürich)

Abstract–The choice of the risk to dose response model that best describes radiation epidemiological data is a main step in radiation related health risk assessment. Often, different models are published which all fit the data similarly well and are all deemed plausible by various groups of the scientific community. With the diversity of available models that have a comparable goodness of fit to the data, a source uncertainty arises when assessing radiation health risks with only one model: the uncertainty arising from model choice. One technique which may be applied to address this source of uncertainty is multi-model-inference (MMI), which allows a composite or averaged model based on several plausible models to be built. For this purpose, different plausible models are fitted to the same dataset and their goodness of fit is quantified via a statistical measure (e.g. AIC or BIC). The composite model is then built as a weighted mean of all the considered models, where the value of the measure is used to calculate the weight for each model. A review of several papers applying MMI in radiation related risk assessment for different outcomes is presented here. Additionally, a new approach to overcome an inherent problem of the MMI approach, which clearly penalizes excess relative risk models with stratified baseline models due to the high number of parameters compared to risk models with parametric baselines, is illustrated. Finally, the advantages of the different statistical measures to quantify the goodness of fit are elucidated and results obtained with a newly proposed multi-method-multi-model inference (M4I) approach are presented. This M4I approach offers a possibility to generate one single risk estimate based on MMI risk estimates calculated with different statistical measures. Generally, it is recommended to consider the uncertainty of model choice, by applying MMI and considering M4I, in radiation risk analyses.

Plausible Biological Mechanisms Underlying Sex Differences Radiation-Induced Lung Cancer Risk

Michael WEIL (Colorado State University)*

Abstract–Some epidemiological studies suggest that women are at greater risk for radiation-induced lung cancer than men, but this observation is not consistent across all studies. In NCRP Commentary No. 32, Scientific Committee 1-27 evaluated evidence for a sex difference in lung cancer risk from radiation exposures, including the biological plausibility that such a difference might exist. A review of rodent studies of radiation-induced lung cancer found inconsistent results on sex differences in risk and the committee noted that the high radiosensitivity of the murine ovary makes mice a poor model for human radiation-induced tumors that may be hormonally driven. In a review of biological mechanisms that underlie sex differences in cancer risk, the committee identified four possibly overlapping mechanisms that could potentially result in greater radiogenic lung cancer risks for women. The first of these is that hormonal differences between men and women, particularly for estrogen levels, puts women at greater risk. The second is that radiation exposure increases risk for a molecular subtype of spontaneous lung cancer that occurs predominantly in women. The third is that X-chromosome reactivation (or failure of inactivation) results in the overexpression of a gene (or genes) that contributes to the development of lung cancer when dysregulated. The fourth mechanism is that sex differences in immune system function underlie a sex difference in radiation associated lung cancer risk.

Reimagining Radiological Risk Communication

Samy EL-JABY (CNSC)*, Emily JANZEN (CNSC), Nicole SIMON (CNSC), Julie BURTT (CNSC), Julie LEBLANC (CNSC), Adam LEVINE (CNSC), Meghan GERRISH (CNSC)

Abstract– The Canadian Nuclear Safety Commission (CNSC) is mandated, within Canada, to "disseminate objective scientific, technical and regulatory information to the public concerning the activities of the Commission and the effects, on the environment or on the health or safety of persons, of the development, production or use of nuclear energy or the production, possession or use of a nuclear substance, prescribed equipment or prescribed information" [1]. Limiting radiation-induced health risks stemming from regulated activities and communicating those risks to affected parties, therefore, is central to CNSC responsibilities.

This mandate is achieved operationally and primarily through the implementation of regulatory dose limits that are based, in part, on recommendations of the International Commission on Radiological Protection (ICRP) and what it judges to be a tolerable radiation detriment [2-3]. Detriment describes the total harm to a population, and their descendants, following radiation exposure and incorporates the weighted probabilities of attributable fatal cancer, non-fatal cancers, severe heritable effects, and length of life lost if the harm occurs. Radiation-induced health risks are communicated directly and indirectly within this framework under the presumption that affected parties understand and acknowledge that regulatory dose limits provide an upper bound on potential, personal harm. This approach, however, has not always proven effective. In many instances, affected parties still want to know how anticipated radiation exposures may impact their health, quality of life, and in the case of radiological contamination of the environment, way of life. Estimates of dose, and adherence to regulatory dose limits, are proving insufficient to meet this objective.

ICRP Task Group 122 on the "Update of Detriment Calculation of Cancer" is actively exploring how the tools, metrics, and approaches traditionally used in radiological risk communication could be improved [4]. One alternative to radiation detriment being considered is the Disability Adjusted Life Year (DALY). One DALY is equivalent to one year of healthy life lost and is given as the sum of years lived with a disability (YLD), following diagnosis of a given disease, and years of life lost (YLL) due to premature death from that same disease [5].

The Institute of Health Metrics and Evaluation (IHME) has administered a Global Burden of Disease project which evaluated contributions to DALY from non-communicable diseases, communicable diseases, and injuries as well as their responsible risk factors (e.g., smoking, air pollution, radon gas) [6]. The IHME effort, though, excluded exposure to artificial radiation sources as a risk factor. In a separate study researchers demonstrated how excess DALY may be calculated from the excess, radiation-induced risk of cancer incidence and mortality [7].

This paper will explore the idea of merging artificial radiation exposure as a risk factor within an IHME-like DALY framework with the hope of facilitating balanced discussions with affected parties regarding the level of risk from licensed activities relative to other, commonplace factors. Challenges associated with implementation within Canada, a country with active engagement with rightsholders and stakeholders throughout the full lifecycle of nuclear facilities and activities, will also be discussed.

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Dose-rate Effects and RBE: Life Shortening and Non-cancer Effects

Gayle WOLOSCHAK (Northwestern University)*

Abstract–Dose-rate effects have been studied using cellular, animal, and human studies. My lab has been working on understanding low-dose rate effects using long-term mouse studies that were done in the US, Europe, and Japan in the last 50 years, and more recently from dog studies from external beam and internal emitters. A focus will be placed on non-cancer endpoints from these studies (particularly fibrosis and other early and late tissue. Distinctions between internal emitters and external exposures will be examined. In addition, the work will be related to TG118 which is currently examining RBE, Quality Factor, and Radiation Weighting Factor. RBE is generally determined experimentally and is used to compare different qualities of radiation; RBE depends on dose, dose-rate, fractionation pattern, and endpoint being measured. Q and wR are both determined by considering experimental data. The committee reviewed past work done by ICRP and concluded that there are some areas not covered in the previous work including large numbers of clinical studies examining proton effects, RBE studies of NASA and other space radiation studies groups, environmental studies, epidemiology studies, and non-cancer effects.

Cancer Risks among Workers

David RICHARDSON (University of California)*

Abstract–Studies of workers exposed to ionizing radiation have made important contributions to our understanding of radiation health effects. This talk provides a brief history of epidemiological studies of populations exposed to ionizing radiation in the workplace. The motivations and challenges of such studies will be discussed, and findings from some recent investigations will be reviewed. Future directions for studies of cancer among radiation-exposed workers will be discussed.

Overview of Recent Radiation Effects Research Foundation (RERF) Research Activities in Epidemiology

Ritsu SAKATA (Radiation Effects Research Foundation)*, Alina BRENNER (RERF), Hiromi SUGIYAMA (RERF), Mai UTADA (RERF), Yuko KADOWAKI (RERF), Ayumi HIDA (RERF), Waka OHISHI (RERF)

Abstract–The Radiation Effects Research Foundation has continued follow-up of the atomic bomb survivors for more than seventy years, taking over from its predecessor, the Atomic Bomb Causality Committee. Increased risk of various cancers and non-cancer diseases associated with increased radiation exposure have been reported over the long history of studies. Interest has increased recently in the effects of radiation on non-cancer diseases. However, the complex etiology of non-cancer diseases poses numerous challenges in assessing the radiation dose response. Many factors need to be taken into account to establish radiation effects that otherwise may be obscured by social and mental conditions relevant to the etiology of non-cancer diseases. The latest mortality report for the Life Span Study (LSS) indicated increased radiation risks for circulatory, respiratory, and digestive diseases and suggested that the radiation-related increase in risks differed by follow-up period. Such temporal differences may be due to a longer latency period of non-cancer diseases than cancer, and reduction of regional differences in exposure to lifestyle risk factors because of population migration and social changes over time. The accumulation of information from the youngest group of survivors with strongest migration out of the original residence after the bombings will help with interpretation of changes in risk patterns. For example, a significant dose response for diabetes mellitus in the sub-cohort of atomic-bomb survivors undergoing biennial health examinations was observed only for Hiroshima but not for Nagasaki survivors. The inconsistent results between the two cities could be due to unassessed and unaccounted risk factors. The follow-up of three fourth of LSS individuals has been completed whereas more than half of survivors who were younger than 20 years at the time of the bombings are still alive. Several recent findings were largely derived from information contributed by younger survivors. Continued follow-up and careful, detailed analyses of available data will be necessary to summarize radiation risks among atomic-bomb survivors.

Non-cancer Effects of Radiation Exposure: Cataracts, Diseases of the Circulatory System and Beyond

Nobuyuki HAMADA (CRIEPI)*, Tamara V. AZIZOVA (SUBI), Mark P. LITTLE (NCI)

Abstract–For radiation protection purposes, the International Commission on Radiological Protection (ICRP) has classified non-cancer effects with a threshold-type dose response relationship as tissue reactions (formerly, deterministic effects), and equivalent dose limits aim to prevent occurrence of such tissue reactions. Evidence has accumulated demonstrating that some non-cancer effects occur years or decades after exposure to radiation at doses and dose rates much lower than previously considered. In 2011, ICRP recommended a nominal threshold of 0.5 Gy to the lens of the eye for cataracts and to the heart and brain for diseases of the circulatory system (DCS), independent of dose rate. Literature published thereafter continues to provide updated knowledge. Elevated risks for cataracts below 0.5 Gy have been reported in several cohorts (e.g., in those receiving protracted or chronic exposures), with suggestions in at least one large cohort of excess risk below 0.1 Gy, so that any high value of dose threshold for cataract appears unlikely with longer follow-up. On the other hand, limited evidence is available for risk of cataract removal surgery, so the progressive nature of radiation cataractogenesis is unclear. There is mounting evidence for risk of normal-tension glaucoma, but the long-standing tenet that the lens is among the most radiosensitive ocular and body tissues appears to remain unaltered. Mechanisms behind the high radiosensitivity of the lens include abnormal proliferation and differentiation of lens epithelial cells. For DCS, elevated risks have been reported in various cohorts, in many with mean dose <0.2 Gy, but the existence or nonexistence of a threshold dose is unclear. There is the possibility that risk per unit dose is greater at lower doses and dose rates. Target organs and tissues for DCS are unidentified, but may include heart, large blood vessels and kidneys. The ICRP threshold dose is the same (0.5 Gy) for DCS and cataracts, suggesting that the circulatory system can be as radiosensitive as the lens, although the excess relative risk per unit absorbed dose for DCS is much less than that for cataracts. However, the underlying mechanisms for DCS even at high doses are incompletely understood. Identification of potential factors (e.g., sex, age, lifestyle factors, coexposures, comorbidities, genetics and epigenetics) that may modify radiation risk of cataracts and DCS would be important. Other non-cancer effects on the "radar" include neurological effects (e.g., Parkinson's disease, Alzheimer's disease, and dementia) for which increased risks have increasingly been reported. Such non-cancer effects also tend to deviate from canonical tissue reactions (with clear thresholds at relatively high dose), necessitating more scientific developments to reconsider the radiation effect classification system and risk management. This talk gives an outline of recent developments in such late-occurring non-cancer effects, and considers the implications for radiation protection.

UNSCEAR Ongoing and Planned Evaluations on Levels and Effects of Radiation Exposure

Jing CHEN (UNSCEAR)*, Anna FRIEDL (UNSCEAR)

Abstract–The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established in 1955 by the UN General Assembly Resolution 913(X), with the mandate to evaluate the latest scientific data on levels and effects (later extended to risks) of exposure to ionizing radiation on humans and the environment; and to provide independent, objective and up-to-date scientific basis for radiation safety.

In the past 68 years, the Committee has published 112 scientific annexes and 5 white papers. The Committee's reports form the scientific basis that underpins radiation protection and represent valuable resources for the scientific community. Countries and international organizations draw on the Committee's scientific evaluations for developing protection frameworks, legal instruments, policies and programmes for technologies employing ionizing radiation.

Several recent UNSCEAR reports have addressed radiation effects including cancer, circulatory disease and beyond. The UNSCEAR 2012 Report addressed the attribution of health effects to exposure to ionizing radiation. An increased incidence of stochastic effects in a population could be attributed to radiation exposure through epidemiological analysis, provided that inherent statistical uncertainties could be overcome. In general, health effects in populations with chronic exposure to radiation at levels that are typical of the global average background levels of radiation cannot be reliably attributed to radiation, mainly due to the uncertainties associated with the assessment of risks at low doses and lack of radiation-specific biomarkers for health effects. Taking into account various sources of uncertainty, the UNSCEAR 2019 Report (annex A) evaluated five combinations of health effects and radiation exposure scenarios (leukaemia incidence after CT scans in childhood; leukaemia mortality after occupational exposure; mortality from all solid cancers after occupational exposure; thyroid cancer incidence after ^{131}I intake during childhood; and cardiovascular disease mortality after exposure to external radiation) to perform quantitative risk evaluation. New evaluations currently in preparation include (i) second primary cancer after radiotherapy, (ii) epidemiological studies of radiation and cancer, (iii) diseases of the circulatory system from radiation exposure, and (iv) nervous system effects of ionizing radiation. At its 70th session in June 2023, the Committee endorsed a preliminary project plan to evaluate radiation effects on the eye (planned to start in 2024), and planned to conduct an evaluation of radiation effects on the immune system within the next years. Although much is known about radiation effects and associated risks, considerable uncertainty remains regarding their quantification. In order to reduce that uncertainty, it is important to follow up the research needs identified by the Committee, e.g. improve and continue epidemiological studies of health effects from exposures to ionizing radiation and develop methods to quantify and combine the various sources of uncertainties. This paper summarizes the research needs identified by the Committee since its 2012 Report.

An Unprecedented Era with Patients Receiving High (>100 mSv) Cumulative Doses: Collective Actions Needed

Madan REHANI (Massachusetts General Hospital, Emeritus member of ICRP, Past President of IOMP, Current President of IUPESM)*

Abstract–Millions of patients benefit from medical imaging every single day. However, studies published in the last 3 years have brought new results never before known. They have opened a new era wherein millions of patients are receiving cumulative doses in three digits of mGy of organ doses or three digits of mSv of cumulative effective dose (CED) every year, only through recurrent computed tomography (CT) exams. One out of 125 patients can be exposed to an effective dose >50 mSv from a single CT exam and 3 out of 10,000 patients undergoing CT exams could potentially receive cumulative effective doses >100 mSv in a single day. Recurrent imaging with CT, fluoroscopically guided interventions (FGI), and hybrid imaging modalities such as positron emission tomography/computed tomography (PET/CT) are more prevalent today than ever before. Data is currently available on the percentage of patients with high doses (>100 mSv) undergoing FGI and PET/CT. Presently, we do not know the cumulative doses that patients may be receiving across all imaging modalities combined. Furthermore, patients with diseases that do not shorten life expectancy significantly are being exposed to high doses of radiation with the potential for radiation effects to manifest during life. Strengthening expertise and creating awareness among all stakeholders is important. However, there is a need to learn from the experience of institutions that have made full use of the best approaches of justification and optimization currently available and still have a large number of patients with high doses. That brings us to the limiting point of current approaches and recommendations. Given the opportunity by the call for suggestions for the new ICRP recommendations, there is a need to think critically to go beyond the implementation of recommendations, despite the fact that in large parts of the world, there is a need for implementation. Thus, both aspects are important. The current situation requires collective actions by various stakeholders. These include imaging device manufacturers for producing imaging machines that can allow sub-mSv imaging, professionals societies of physicians, radiographers/technologists, medical physicists, regulators and radiation protection experts to ensure appropriate utilization of technology and implementation of guidance. Additionally, the international organizations and bodies involved in radiation protection need to review recommendations as we appear to be at a limiting point where full application of the current principles of justification and optimization leaves us with a large number of patients with high doses. The approaches used for safety in the use of drugs provide some guidance in developing new recommendations and approaches.

The NEA's Efforts to Strengthen Radiological Protection Expertise and Public Awareness

Jacqueline GARNIER-LAPLACE (OECD Nuclear Energy Agency)*, Jan-Hendrik KRUSE (NEA), Christopher MOGG (NEA), Greg LAMARRE (NEA)

Abstract–The NEA supports the ICRP's position on strengthening radiological protection expertise, as outlined in the Vancouver Call for Action, and is actively working in a number of areas to reflect the priorities of NEA member countries on this complex issue. Through the successive work programmes of its Committee on Radiological Protection and Public Health and other technical committees, the NEA is making progress on how a strategy to strengthen radiological protection expertise can add value to public awareness on radiological protection related issues. In addition to the acceleration of education and the transfer of knowledge and know-how to younger generations of radiological protection experts, the other strategic pillars for progress must take into account two major global changes currently taking place in societies.

Firstly, a large number of member countries have undertaken a high-level reflection on the relative role that nuclear energy and other energy sources could play in a rapid and effective transition towards the goal of zero net carbon emissions. Radiological protection experts are called upon more than ever to contribute to the development of sound, science-based policies and to the adaptation/modernisation of existing regulatory frameworks to changing and innovative technologies. The associated impacts on human well-being and on maintaining/improving the quality of the environment need to be analysed using holistic and robust approaches to demonstrating protection.

More interactions and dialogues between academic research communities, policy makers, regulators, as well as the public, are required, specifically in the area of human and ecological health risk of low doses in order to examine, understand and potentially reduce the remaining uncertainties and knowledge gaps. The link between research and expertise needs to be strengthened so that the most significant research findings can be appropriately translated into policy and regulation, as well as in plain language. Given the wider context of the nuclear industry, including the rapid development of new technologies, nuclear expansion in an increasing number of countries, and accelerating decommissioning in other countries, advancing our knowledge and understanding, as well as improving communications about low-dose research, have important implications.

To increase the chances of success of a stronger link between research and decision makers, a "risk-informed" society, based on better dissemination of information throughout society, is needed to improve understanding and awareness of nuclear issues. This must include approaches and tools that enable citizens to form their own opinions and make their own decisions for each situation perceived or assessed as being "at risk". Involving civil society, from the idea to the implementation of the technology, could help define priorities in research portfolios and reduce discrepancies between real and perceived risk.

The presentation will illustrate the NEA's efforts with concrete examples of current and planned activities.

PIANOFORTE : a European Research Partnership to Strengthen Expertise in Radiation Protection

Jean-Christophe GARIEL (IRSN)*

Abstract–The ambition of the PIANOFORTE Partnership (2022-2027) is to improve radiological protection of members of the public, patients, workers and environment in all exposure scenarios and provide solutions and recommendations for optimised protection in accordance with the Basic Safety Standards. Research projects focusing on identified research and innovation priorities will be selected through a serie of three competitive open calls.

The input to define the research priorities will be based on the priorities defined in the Joint Road Map (JRM) developed during the H2020 CONCERT European Joint Programme but also on the results of ongoing H2020 projects and on the expectations expressed by other actions carried out in other European programmes, in particular the SAMIRA (Strategic Agenda for Medical Ionising Radiation Application) action plan. High priority will be dedicated to medical applications considering that 1) medical exposures are, by far, the largest artificial source of exposure of the European population and 2) the fight against cancer is a top priority of the present European Commission. In order to ensure an appropriate continuity in the research goals and methodologies, in line with the contents of the CONCERT Joint Road Map, two other priorities have been identified to further understand and reduce uncertainties associated with health risk estimates for exposure at low doses in order to consolidate regulations and improve practices and to further enhance a science-based European methodology for emergency management and long-term recovery.

Once the research priorities defined, the open call system will promote excellence in science and widening participation through a process open to the whole radiation protection community. Beyond the research actions, the selected projects will be able to benefit from the system of sharing and mutualisation of infrastructures that will be implemented at the European level. This will be accompanied by education and training schemes for health workforce and young scientists to increase Europe's research capacity in the field.

A crucial point of the projects will be the transfer from outputs into outcomes that will have impacts on the different target groups. Particular attention, mentioned in the selected calls, will be given to data management (FAIR principle) as well as to communication and dissemination of knowledge in the spirit of complying with the principles of open science.

The vision supported by this Partnership is to provide a pan-European scientific and technological basis for a robust system of protection and more consolidated science-based policy recommendations to decision makers in all these different fields.

HERCA Perspectives on Practical Aspects of Strengthening Expertise

Carol ROBINSON (DSA/HERCA)*

Abstract–HERCA (Heads of the European Radiological Protection Competent Authorities) is a voluntary association where the Heads of the authorities work together to identify common significant radiation protection issues and propose common practical solutions, whenever possible. HERCA's goal is to contribute to a high level of radiation protection throughout Europe by, among other things, building and maintaining a comprehensive European network of the chief radiation safety regulators in Europe. HERCA's work involves sharing experiences and best practices among the various authorities and by learning from each other, strengthening expertise.

HERCA has established 6 working groups to share experiences on: education and training; emergency preparedness and response; medical applications; natural radiation sources; research and industrial sources and practices; and veterinary applications. These groups are actively working to strengthen expertise in particular key areas, often by means of focused workshops and, in some cases, by joint inspection activities. Some examples of this work will be presented.

In May 2022, HERCA prepared a paper on its reflections on the revision of the System of Radiological Protection, to ICRP, based on input from HERCA's members on experience in the practical application of the current RP System in their organisations and countries. HERCA concluded that the system was generally fit for purpose and scientifically solid. However, HERCA's members identified areas where some improvements would be welcome.

HERCA also works to raise public awareness of radiation protection and its work through publications and a user-friendly website. Communication issues are presented in a paper by HERCA in the relevant session of this symposium.

Strengthening Expertise and Raising Public Awareness is a Part of Radiation Protection Culture : Example in Healthcare

Bernard LE GUEN (International Radiation Protection Association)*,

Abstract–Managing population exposure from medical technologies is more than a purely scientific and technical matter. For example, today there is a general recognition of the importance of considering societal values – as they evolve – and involving patients, families, and the public in the process of decision-making about benefits, costs, and risks.

The patients, together with their community and caregivers, have already been identified as key stakeholders in healthcare. Patient's rights also carry with them responsibilities in how a patient and their family members should act in relation with the health care facility. Engaging and empowering patients and families on risk to ionizing radiation exposure support the journey to safer health care.

Risks should be defined as those that we know, those that are potential (or probabilistic), and those where there is uncertainty in the scientific literature (or that we do not yet fully understand).

Patients have repeatedly reported a desire to know both dose and risk when asked. Informed consent rests on transparency about the benefits and risks of diagnostic and treatment interventions, and on the disclosure of the patient's diagnosis and prognosis.

The patient's concerns must be respected and addressed, he must be informed . Patient and family perceptions of the culturally appropriate degree of disclosure may differ, and so it is important to inquire with the patient themselves. In the disclosure of radiation risks and complications, it is important to consider the cognitive and emotional burden that inappropriate or excessive detail may have on.

There is an opportunity to engage such representation not only in broad patient safety issues but also in relation to specific aspects of radiation safety culture. This also had a positive impact on the safety communication and dialogue between the members of the team involved in the patient's care.

This will be a two-way communication process, which provides information and education on radiation safety issues to those who will be on the receiving end of both the benefit and the risk, and allows organizations and professional stakeholders to learn from patient experience and priorities.

Dialogue is very important in a two-way communication process to work towards an active informed decision-making process for patients. Not all health professional knows and understand RP, so their awareness about radiation benefits and risks should be raised as well.

Patients can influence management at an organizational level through patient advocacy groups, inclusion of patient representatives on appropriate committees and a variety of feedback opportunities.

Engagement and empowerment of patients on risk awareness contributes to quality and safety of care, facilitates communication between health professionals and patients in a respectful environment and improves dialogue with patients and families – all attributes of a positive safety culture.

Safety culture is not just the sum total of rules, policies, procedures and processes. The real building blocks of safety are trust, communication, and culture.

Raising Public Awareness on Radiation Science

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Abstract–The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) was established in 1955 by the United Nations General Assembly with the mandate to undertake broad assessments of the sources of ionizing radiation and its effects on human health and the environment. Its independent scientific evaluations carried out over the past 67 years represent a rigorous and reliable source of scientific information on global levels and effects of exposure to ionizing radiation. Its findings are used by governments and international organizations to establish radiation protection policies and standards, and to make other decisions related to the use of ionizing radiation. The Committee's work is also of significant interest to other stakeholders, the media and the public in general.

At the 70th session in June 2023, the Committee continued to call upon all Member States of the United Nations and international organizations to invest in scientific education and programs at all levels and to support radiation research programs to ensure the crucial work of the Committee can be sustainably maintained in the future.

This paper summarizes the recent activities and initiatives, undertaken by the Committee and its secretariat on implementation of the Committee's public information and outreach strategy (2020–2024) and the extended outreach activity on the Fukushima Daiichi Nuclear Power Station accident. The primary aim of the outreach strategy and associated activities was to deepen understanding about the work of the Committee and its general findings on radiation sources, levels, and effects, particularly among decision-makers and their advisers, educators and students, the public and the media. Examples of successful and well received initiatives include the UNEP Booklet "Radiation: Effects and Sources" that is available for free download in 15 languages for communicating radiation science to the public in easy understandable way; update of the UNSCEAR website (www.unscear.org) and its ongoing translation to official languages of the United Nations; engagement with students and young professionals; organization of topical webinars on medical and occupational exposures to ionizing radiation, and biological mechanisms relevant for the inference of cancer risks from low-dose and low-dose-rate radiation in 2022; as well presentation and dialogue with members of the public (e.g. Iwaki, Japan, July 2022).

Capacity and Expertise Building in Radiation Protection and Raising Public Awareness Core to IAEA's Mission

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Abstract–IAEA promotes a strong and sustainable global nuclear safety and security framework in Member States, to protect people, society, and the environment from the harmful effects of ionizing radiation. For this purpose, IAEA develops safety standards to protect the health and minimize the danger to people's life and property associated with such use and ensures their application.

To assist Member States with application of its safety standards, IAEA offers a wide spectrum of training and capacity-building programmes including training courses, e-learning, webinars, technical meetings, review missions, workshops and conferences, promotional publications and web-based information.

Recently increased widespread application of radiation and nuclear technologies have led to a steady increase of the number of workers who might be exposed to radiation in the course of their work. IAEA programme in radiation safety promotes an internationally harmonized approach. As an example of activity in providing for application of its safety standards, IAEA developed with several other international organizations the Occupational Radiation Protection Call-for-Action comprising nine key areas of actions among which strengthening assistance to countries with less developed programmes for occupational radiation protection.

More than 95 per cent of the radiation dose the global population is exposed to from man-made sources, stems from medical exposures. IAEA works on preventing patients and medical staff to be exposed to unnecessary and unintended radiation, while ensuring that radiation doses to patients are commensurate with the medical purpose through a dedicated radiation protection programme and activities. The dedicate Radiation Protection of Patients (RPOP) website informs health professionals and patients and public on the safe use of radiation in medicine.

IAEA offers several peer review services and associated self-assessments to provide a means of evaluating the radiation safety framework, monitoring progress and for identifying gaps and areas for further work and improvements in capacity building. IAEA recommends that a systematic approach to training needs to be integrated into the management systems of all organizations relevant to nuclear safety and that safety issues need to be incorporated into the curricula of higher education and training.

Whereas capacity building aims to strengthen people's knowledge and skills to engage with radiation safety and radiation protection, awareness-raising efforts aim to generate and stimulate sensitivity to issues of radiation protection and radiation safety. Apart from a performant website, a way of raising public awareness are IAEA's wide range of products and services to support Member States in their stakeholder engagement efforts in nuclear programmes. Engagement with stakeholders is one of the fundamental safety principles.

Through its activities in raising public awareness in the field of radiation safety, IAEA recognizes that engaging with a wide range of stakeholders can enhance public awareness, understanding and confidence in the application of nuclear science and technology, and strengthen communication among the key organizations involved. IAEA provides guidance on communicating and engaging with both internal and external stakeholders. It regularly holds national and regional workshops on stakeholder engagement and integrates this issue into its review missions.