ICRP 2015

3rd International Symposium on the System of Radiological Protection

Date | October 20-22, 2015

Venue | Ballroom 1F, Convention Building, Mayfield Hotel & Resort

ICRP
INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION

KARP
Korean Association for Radiation Protection

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* KAEEA: Korea Atomic Energy Enterprise Association
KANDT: Korea Association for Non-Destructive Testing
KARA: Korean Association for Radiation Application
KARP: The Korean Association for Radiation Protection
KINS: Korea Institute of Nuclear Safety
KOC: KARP-ICRP 2015 Organization Committee
KONICOF: Korea Nuclear International Cooperation Foundation
KORAD: Korea Radioactive Waste Agency

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*** MAYFIELD HOTEL & RESORT**

GENERAL INFORMATION

VENUE LAYOUT

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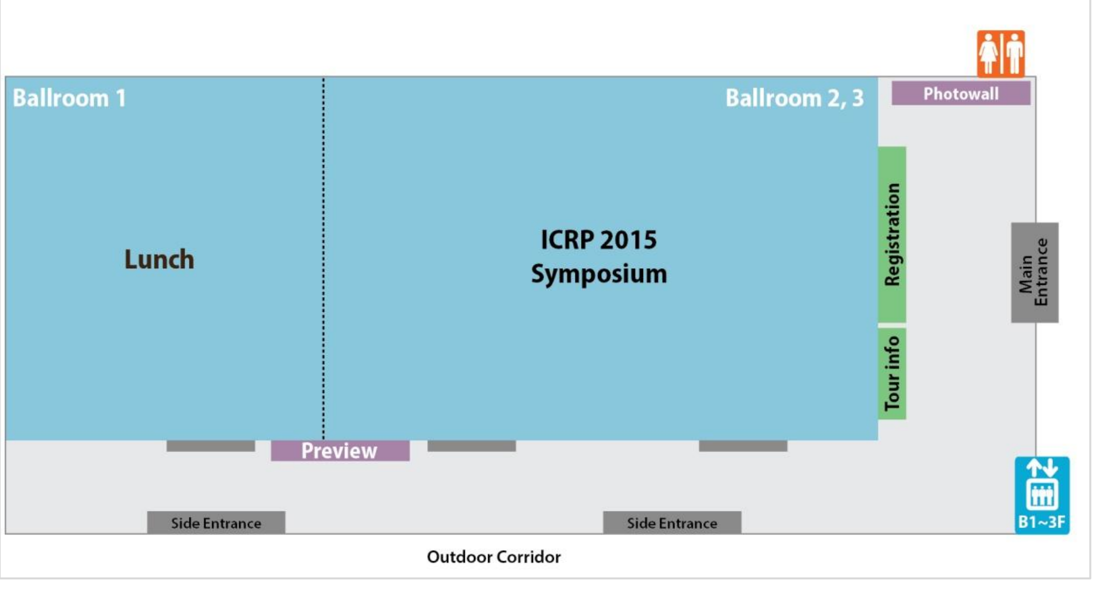


Wi-Fi

* Complimentary use of LAN cable and High-speed Wireless Internet in your room
* Complimentary use of Wi-Fi at the hotel

LUNCH

* Date & Time: 20th (Tue) 12:30-14:00 / 21st (Wed) 12:00-13:30 / 22nd (Thu) 12:00-13:30
* Venue: Ballroom 1, 1F, Convention Building **AND** Calla, 3F, Convention Building

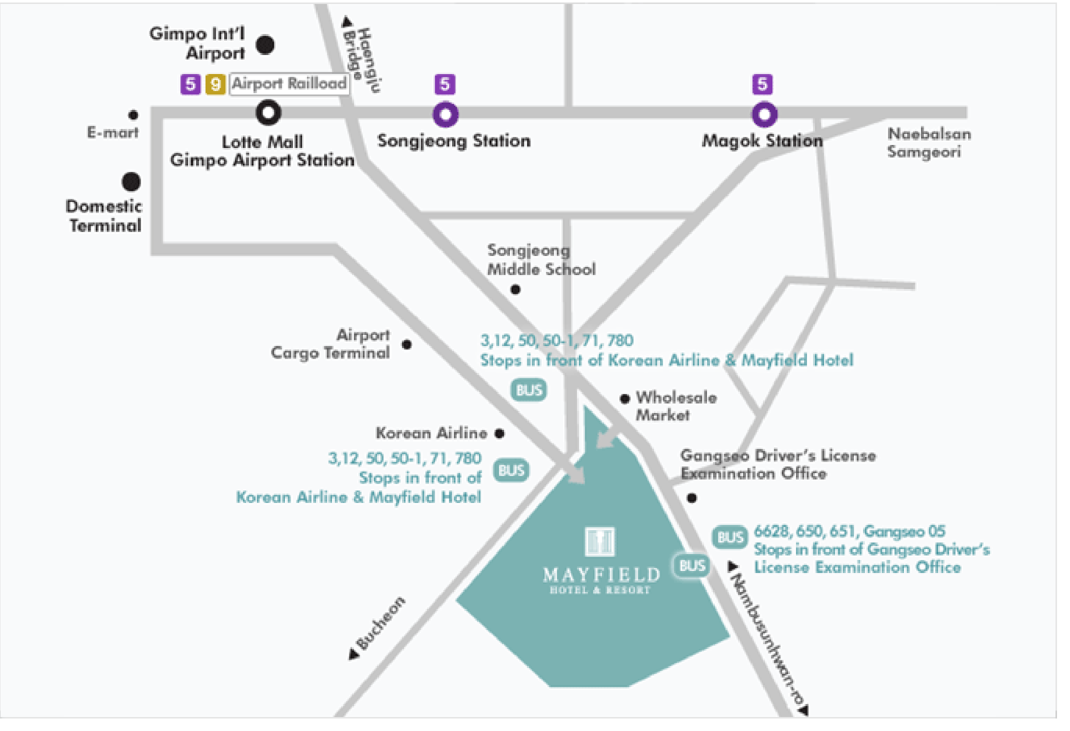
AWARDS BANQUET

* Date & Time: 21st (Wed) 18:00-21:30
* Venue: Bell Tower Garden

GENERAL INFORMATION

MAYFIELD HOTEL & RESORT

* Address: 94 Banghwa-daero, Gangseo-gu, Seoul, Korea
* TEL: +82-2-2660-9000
* FAX: +82-2-2660-9001
* E-MAIL: maymaster@mayfield.co.kr



ICRP SECRETARIAT

* Room: 1F, Convention Building

KOC SECRETARIAT

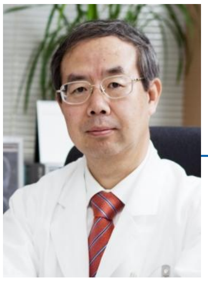
* Room: 3F, Convention Building
* TEL: +82-2-765-7996
* FAX: +82-303-3441-7996
* E-MAIL: icrp2015.korea@gmail.com

Welcome Messages

C. Cousins

ICRP Chair
Addenbrooke's Hospital, Cambridge, UK

It is a great pleasure for ICRP to hold its 3rd International Symposium on the System of Radiological Protection in Seoul, Korea. Continuing the success of the first two Symposia held in USA and UAE, I am sure this Symposium will offer opportunity for many professionals to discuss the challenges faced in radiological protection today and in years to come. These biennial symposia are a cornerstone of ICRP's efforts to engage as many individuals and organisations working in radiological protection as possible, and to collaborate on ideas and in areas of mutual interest. The diversity of the programme should stimulate both discussion and debate. I would very much like to thank our Korean colleagues for their dedicated time and effort in helping to organise this Symposium, and our supporters for helping make ICRP 2015 possible.



Il Han Kim

President, ICRP 2015 Organization Committee
President, The Korean Association for Radiation Protection (KARP)

On behalf of the Local Organizing Committee and the Korean Association for Radiation Protection, I would like to welcome all the participants to the 3rd ICRP Symposium.

We have worked with all our efforts along with the ICRP for the success of the ICRP 2015 Symposium for more than 2 years. We have been delighted to have an opportunity to contribute to the sustainable progress in the development and implementation of the System of Radiological Protection.

We are grateful to the Korea Nuclear Safety and Security Commission, the Government of the Republic of Korea for their support. We would like to express our gratitude to the Korea Atomic Energy Research Institute, the Korea Institute of Nuclear Safety, the Korea Hydro & Nuclear Power Co. Ltd, the Doosan Heavy Industries & Construction, the KEPCO E&C and other sponsors in Korea.

We are confident that the 3rd ICRP Symposium will be an excellent forum for the exchange of knowledge and achievement in radiological science, and for the promotion of radiation protection culture or ethics, and for the enhancement of public communication for radiation safety and protection.

We also hope that participants will enjoy an extraordinary cultural experience in Seoul, the capital city of Korea since 1394.

PROGRAM

Tuesday, October 20

09:00-09:30	**Welcome Remarks**
09:00-09:10	Claire Cousins (ICRP Chair)
09:10-09:20	Unchul Lee (NSSC Chair, Korea)
09:20-09:30	Il Han Kim (KARP President, Korea)
09:30-12:30	**Session 1: Advancing Together After 87 Years**
	Co-Chairs: Claire Cousins (ICRP Chair), Christopher Clement (ICRP Scientific Secretary)
09:30-09:50	The Future of ICRP – Towards a Centenary and Beyond
	Claire Cousins (ICRP Chair)
09:50-10:10	Overview of ICRP Committee 1: Radiation Effects
	William Morgan (ICRP C1 Chair)
10:10-10:30	Overview of ICRP Committee 2: Doses from Radiation Exposure
	John Harrison (ICRP C2 Chair)
10:30-11:00	**Break**
11:00-11:20	Activities of Committee 3 on Protection in Medicine
	Eliseo Vaño (ICRP C3 Chair)
11:20-11:40	Overview of ICRP Committee 4 Application of the Commission's Recommendations
	Donald Cool (ICRP C4 Chair)
11:40-12:00	Protection of the Environment - Activities of ICRP Committee 5
	Carl-Magnus Larsson (ICRP C5 Chair)
12:00-12:30	Q&A
12:30-14:00	**Lunch**
14:00-17:00	**Session 2: Exploring Existing Exposure Situations**
	Co-Chairs: Jean-François Lecomte (ICRP C4), Agneta Rising (WNA)
14:00-14:25	Understanding Existing Exposure Situations
	Jean-François Lecomte (ICRP C4)
14:25-14:50	Cosmic Radiation in Aviation: The Radiological Protection of Air France Aircraft Crews
	Gérard Desmaris (Air France, France)
14:50-15:15	Measuring, Discussing and Living Together – What We Learned from Four Years in Suetsugi
	Ryoko Ando (Ethos in Fukushima, Japan)
15:15-15:45	**Break**
15:45-16:10	Contaminated Sites from the Past – EPA Experience
	Michael Boyd (ICRP C4)
16:10-16:35	Protection of the Environment in Existing Exposure Situation
	David Copplestone (ICRP C5)
16:35-17:00	Panel Discussion

PROGRAM | **Wednesday, October 21**

09:00-12:00	**Session 3: Radiological Protection in Medicine Today**
	Co-Chairs: Donald Miller (ICRP C3), Il Han Kim (KARP)

09:00-09:25 Eight Decades of ICRP Recommendations in Medicine: A Perspective
Pedro Ortiz-López (ICRP C3)

09:25-09:50 Current Issues in the Roles of Radiologists, Medical Physicists, Radiographers, and Manufacturers in Korea
Kyung-Hyun Do (University of Ulsan, Korea)

09:50-10:15 Current Global and Korean Issues in Safety of Nuclear Medicine Procedures
Ho Cheon Song (Chonnam National University Hospital, Korea)

10:15-10:45 Break

10:45-11:10 Radiological Protection in Ion Beam Radiotherapy: A Practical Guidance for Clinical Use of New Technology
Yoshiharu Yonekura (ICRP C3)

11:10-11:35 A Web-based ICRP Resource to Inform Healthcare Providers on the Risks and Benefits of Ionizing Radiation in Medicine
Sandor Demeter (ICRP C3)

11:35-12:00 Panel Discussion

12:00-13:30 Lunch

13:30-17:00	**Session 4: The Science Behind Radiation Doses**
	Co-Chairs: Jaiki Lee (ICRP MC), Hans Menzel (ICRU Chair, ICRP MC)

13:30-13:55 Dose Coefficients of ICRP – Their Computational Development and Current Status
Wesley Bolch (ICRP C2)

13:55-14:20 The Operational Quantities and New Approach by ICRU
Akira Endo (ICRP C2)

14:20-14:45 The Reference Phantoms: Voxel vs. Polygon
Chan Hyeong Kim (ICRP C2)

14:45-15:10 Assessment and Interpretation of Internal Dose: Uncertainty and Variability
Francois Paquet (ICRP C2)

15:10-15:45 Break

15:45-16:10 The Use of Effective Dose
John Harrison (ICRP C2 Chair)

16:10-16:35 Dosimetry for Animals and Plants – Contending Biota Diversity
Alexander Ulanovsky (ICRP C5)

16:35-17:00 Panel Discussion

PROGRAM | **Thursday, October 22**

09:00-12:00	**Session 5: New Developments in Understanding Radiation Effects** **Co-Chairs:** Werner Rühm (ICRP C1), Malcolm Crick (UNSCEAR)

09:00-09:25	New ICRP *Publication 131*: Stem Cell Biology with Respect to Carcinogenesis Aspects of Radiological Protection *Jolyon Hendry (Manchester University, UK)*
09:25-09:50	Radiation-related Risks of Non-cancer Outcomes in the Atomic-bomb Survivors *Kotaro Ozasa (RERF, Japan)*
09:50-10:15	Dose Rate Effects in Radiation Biology and Radiation Protection *Werner Rühm (ICRP C1)*
10:15-10:45	Break
10:45-11:10	Evidence for Variation in Human Radiosensitivity and its Potential Impact on Radiological Protection *Simon Bouffler (ICRP C1)*
11:10-11:35	Analysis of Individual Difference of Radiosensitivity using Genome-editing Technique *Shinya Matsuura (Hiroshima University, Japan)*
11:35-12:00	Panel Discussion
12:00-13:30	Lunch

13:30-16:35	**Session 6: Ethics in Radiological Protection** **Co-Chairs:** Jacques Lochard (ICRP Vice Chair), KunWoo Cho (ICRP C4)

13:30-13:55	The Ethical Foundations of the Radiological Protection System *KunWoo Cho (ICRP C4)*
13:55-14:20	The Focal Role of Tolerability and Reasonableness in the Radiological Protection System *Thierry Schneider (CEPN, France)*
14:20-14:45	The Ethics of Radiological Risk Governance – The Justice of Justification as a Central Concern *Gaston Meskens (SCK-CEN, Belgium)*
14:45-15:15	Break
15:15-15:40	The Ethical Foundations of Environmental Radiological Protection *Deborah Oughton (ICRP C4)*
15:40-16:05	Are the Core Values of the Radiological Protection System Shared across Cultures? *Friedo Zölzer (University of South Bohemia, Czech)*
16:05-16:35	Panel Discussion

16:35-17:30	**Closing Remarks** Claire Cousins (ICRP Chair) Jacques Lochard (ICRP Vice Chair) Jacques Repussard (IRSN, France)

The Future of ICRP – Towards a Centenary and Beyond

C. Cousins

ICRP Chair
Addenbrooke's Hospital, Cambridge, UK

The International Commission on Radiological Protection (ICRP) has now been in existence for 87 years, since its establishment in 1928. It remains a leading authority in radiological protection, and its role is to provide recommendations and guidance on all aspects of protection against ionising radiation. The published recommendations of ICRP form the basis of radiation safety standards worldwide. Modernisation of the organisation in recent years has led to new initiatives and changes. These have included writing a strategic plan and code of ethics for the first time. Elections for Committee membership have been through open nominations, a process which will shortly be repeated for the membership in the next term, commencing on July1, 2017. Biennial symposia were created in 2011 and the success of the first two has secured this venture as a regular part of the ICRP calendar. ICRP has also revised its method of working with other organisations by establishing Special Liaison Organisation status. This has improved collaboration with the ever expanding number of organisations working in radiological protection, with whom it is important that ICRP has essential links. ICRP is also looking to, in the future, review its legal basis and governing documents to ensure best practices are being followed as ICRP evolves. In addition, the strategic plan will be regularly reviewed and updated. Other ways of working with organisations will be considered to further strengthen engagement with wider radiological protection community. ICRP aims to make its publications available at low or no cost, and to produce both a plain language overview of the system of radiological protection and a summary of the recommendations. These activities will require additional financial resource and ICRP has embarked on a fundraising campaign to support such efforts. ICRP can be proud of its history of maintaining its independence and preserving the wide respect earned over many years. Despite long traditions, ICRP has evolved and will continue to do so to perform as a more modern organisation as it heads towards a centenary and beyond.

Overview of ICRP Committee 1: Radiation Effects

W.F. Morgan

ICRP Committee 1 Chair
Pacific Northwest National Laboratory, Richland, WA, USA

ICRP Committee 1 addresses issues pertinent to tissue reactions, risks of cancer and heritable diseases, radiation dose responses, effects of dose rate and radiation quality. In addition, it reviews data on effects of radiation on embryo/fetus, genetic factors in radiation response, as well as uncertainties in providing judgments on radiation-induced health effects. The Committee advises the Main Commission on the biological basis of radiation-induced health effects and how epidemiological, experimental and theoretical data can be combined to make quantitative judgments on health risks to humans. The emphasis is on low radiation doses, in the form of detriment-adjusted nominal risk coefficients, where there are considerable uncertainties in both the biology and epidemiology. Furthermore, Committee 1 reviews data from radiation epidemiology studies and from publications on the molecular and cellular effects of ionising radiations relevant to updating the basis of the 2007 Recommendations found in *Publication 103*. This presentation will provide an overview of the activities of Committee 1, the updated work of the Task Groups and the Working Parties, and the future activities being pursued by Committee 1.

Overview of ICRP Committee 2: Doses from Radiation Exposure

J. Harrison

ICRP Committee 2 Chair
Public Health England, Centre for Radiation, Chemical and Environmental Hazards, Oxon, UK

The focus of the International Commission on Radiological Protection (ICRP) Committee 2 work is the computation of new dose coefficients following *Publication 103* The 2007 Recommendations. It is important that the methodology used to calculate doses is examined and updated as necessary to ensure that it is used in accordance with the most current scientific knowledge. For the first time, a set of reference computational phantoms is being developed, based on medical imaging data, and used for radiation transport calculations. Biokinetic models used to describe the behaviour of radionuclides in body tissues are being updated, also leading to changes in organ doses and effective dose coefficients. Dose coefficients for external radiation exposure of adults calculated using new reference phantoms were issued as *Publication 116*, jointly with the International Commission on Radiation Units and Measurements (ICRU). Forthcoming reports will provide internal dose coefficients for radionuclide inhalation and ingestion by workers and associated bioassay data. Work is in progress to revise internal dose coefficients for members of the public and for the first time to provide reference values for external exposures of the public. The Committee is also working with Committee 3 on dose coefficients for radiopharmaceuticals and leading a cross-Committee initiative to give advice on the use of effective dose. Joint work with ICRU is in progress to update the operational quantities used in the measurement of external radiation exposures.

Activities of Committee 3 on Protection in Medicine

E. Vano[a,b], D.L. Miller[c], M.M. Rehani[d]

[a]*ICRP Committee 3 Chair*

[b]*Radiology Department, Complutense University, Madrid, Spain*

[c]*Center for Devices and Radiological Health, Food and Drug Administration, USA*

[d]*Massachusetts General Hospital, Harvard Medical School, USA*

The International Commission on Radiological Protection (ICRP) Committee 3 develops recommendations and guidance for protection of patients, staff, and the public against radiation exposure when ionising radiation is used for medical diagnosis, therapy, or biomedical research. This paper presents a summary of the work that Committee 3 has accomplished in the past few years, and also describes its current work. The most recent documents published by the Commission that relate to radiological protection (RP) in medicine are: *Publication 129* Radiological Protection in Cone-Beam Computed Tomography (CBCT); *Publication 127* Radiological Protection in Ion Beam Radiotherapy; *Publication 121* Radiological Protection in Paediatric Diagnostic and Interventional Radiology; *Publication 120* Radiological Protection in Cardiology; and, *Publication 117* Radiological Protection in Fluoroscopically Guided Procedures Outside the Imaging Department. In addition, the Committee 3 worked with Committee 2 to produce *Publication 128* Radiation dose to patients from radiopharmaceuticals: A compendium of current information related to frequently used substances. A new document on diagnostic reference levels in medical imaging will provide specific advice for interventional radiology, digital imaging, CT, nuclear medicine, paediatrics and multimodality procedures. The Committee 3 is also working on guidance for occupational RP in brachytherapy and on guidance for occupational protection issues in interventional procedures, with particular attention to the 2011 recommendations on occupational dose limit to the lens of the eye. Other currently prepared documents deal with justification, RP in therapy with radiopharmaceuticals, RP in medicine related to individual radiosusceptibility, appropriate use of effective dose, and guidance for health care practitioners on radiation and patient protection. Committee 3 has also suggested specific priorities for research on RP in medicine to the Main Commission.

Overview of ICRP Committee 4 Application of the Commission's Recommendations

D.A. Cool

ICRP Committee 4 Chair
Electric Power Research Institute, Charlotte, NC, USA

The International Commission on Radiological Protection (ICRP) Committee 4 develops principles and recommendations on radiological protection of people in all exposure situations. The Committee meeting in 2014 was hosted by GE Healthcare in Arlington Heights, Illinois, USA, 27 July – 1 August, 2014. The Committee 4 programme of work encompasses several broad areas of focus, including a series of reports covering various aspects of existing exposure situations, leading the ICRP effort to update and elaborate recommendations in light of the accident at Fukushima Daiichi for emergencies and living in contaminated areas, elaborating the underpinnings of the system of protection, and developing focused reports on specific topic areas in consultation with organisations in formal relations with ICRP. The Committee has Task Groups working on Naturally Occurring Radioactive Material, Cosmic Radiation in Aviation, Updates of ICRP *Publication 109* and *111*, Ethics of Radiological Protection, Surface and Near Surface Disposal of Solid Radioactive Waste, and Exposures Resulting from Contaminated Sites from Past Industrial, Military and Nuclear Activities. In addition, there is a Working Party on Tolerability of Risk, and ongoing work with other organisations.

Protection of the Environment - Activities of ICRP Committee 5

C-M. Larsson

ICRP Committee 5 Chair
Australian Radiation Protection and Nuclear Safety Agency, Miranda NSW, Australia

Protection of the environment is integral to the system of radiological protection as outlined in *Publication 103* The 2007 Recommendations of the International Commission on Radiological Protection; the Commission's activities in this area are mainly being pursued within Committee 5. The approach to environmental radiation protection and its alignment with environmental protection more broadly was outlined already in *Publication 91*, the cornerstones of the environmental protection system and relevant databases were provided in *Publications 108* and *114*, and its application in planned, existing and emergency exposure situations was outlined in *Publication 124*. In short, the system centres on 12 reference animals and plants (RAPs) with broad relevance in terms of environmental protection based on their ubiquity and significance, using a multitude of criteria as described in *Publication 108*. The databases comprise general biology of the RAPs, transfer parameters, dose conversion factors and effects data. Derived Consideration Reference Levels (DCRLs) were established for each RAP, representing a band of dose rates within which there is likely to be some chance of deleterious effects of ionising radiation for individuals of that type of RAP. The system has demonstrated its robustness and applicability in a number of assessments. Current work looks at consolidating the databases through improved dosimetry and understanding of dose-effects relationship. A newly established Task Group compiles RAP-specific reference information into 'monographs', with the view of updating information, improving flexibility and supplementing data where such are currently missing. For certain scenarios, more precise and ecosystem-specific protection benchmarks (e.g. reference values of dose rate for environmental protection as outlined in *Publication 124*) may be justified, which would have to be informed by consideration of *representative organisms* (i.e. *representative* of a particular ecosystem and relevant to the assessment context). The Committee's future programme of work includes development of principles for generation of relevant databases based on existing generic databases for *reference* animals and plants for consideration of ecosystem characteristics more broadly, and application of the methodology in a limited number of scenario.

Understanding Existing Exposure Situations

J-F. Lecomte

ICRP Committee 4
nstitute for Radiological Protection and Nuclear Safety (IRSN), Fontenay-aux-Roses Cedex, France

The International Commission on Radiological Protection (ICRP) *Publication 103* removed the distinction between practices and interventions, and introduced three types of exposure situations: existing, planned and emergency. It also emphasised the optimisation principle in connection with individual dose restrictions to all controllable exposure situations. Existing exposures situations are those resulting from sources, natural or man-made, that already exist when a decision on control has to be taken. They have common features to be taken into account when implementing the general recommendations, such as: the source may be difficult to control; all exposures cannot be anticipated; protective actions can be implemented only after characterisation of the exposure situation; times are generally required to reduce exposure below the reference level; levels of exposure are highly depending on individual behaviour; a wide spread distribution of the individual dose is presented; exposures at work may be adventitious and not considered as occupational exposure; there is generally no potential for accident; and, many stakeholders have to be involved and many factors need to be considered. ICRP is currently developing a series of publications related to the practical implementation of *Publication 103* to some existing exposure situations: exposure from radon, from cosmic radiation in aviation, from processes using naturally occurring radioactive materials and from contaminated sites due to past activities.

Cosmic Radiation in Aviation: The Radiological Protection of Air France Aircraft Crews

G. Desmaris

Air France, Occupational health service IO.ZM, Paris, France

Cosmic radiation in aviation has been a concern since the 1960s. Measurements have been performed for several decades by Air France. Results show that aircraft crew members receive 3 to 4 mSv per year for 750 boarding hours. Compliance with the trigger level of 6 mSv per year is achieved by route selection. Working schedules for pregnant pilots allow them to keep dose to the fetus under 1 mSv. Each crew member is informed about her/his dose and the potential health impact. The future ICRP report on cosmic radiation in aviation will provide updated guidance. A graded approach proportionate to the level of exposure is recommended to implement the optimisation principle. The objective is to keep the exposure of the most exposed aircraft members to reasonable levels. The Commission also recommends to disseminate information and to raise awareness about cosmic radiation, in order to favour an informed decision among all concerned stakeholders.

Measuring, Discussing and Living Together – What We Learned from Four Years in Suetsugi

R. Ando

Ethos In Fukushima, Fukushima, Japan

In cooperation with radiation protection experts and using radiation measurements, residents of Suetsugi, Iwaki-shi in Fukushima have been striving to reshape their life. Suetsugi lies within the 30 km radius of the Fukushima Daiichi Nuclear Power Plant so the residents have had serious reservations about continuing their life there after the accident. Today, radiation remains a line dividing their lives; dose measurements directly affect their daily decision making. Assisted by medical and scientific specialists, the residents faced this challenging situation by measuring their own exposures and discussing the results among themselves. Since 2012, Suetsugi residents have used personal dosimeters, made trips for whole body counter measurements, and acquired food contamination monitors. The results have always been openly shared among the residents. Obtaining and discussing their own data has been crucial to understand the various results and to practice radiation protection in their daily routine. The four-year experience in Suetsugi is an example of cooperation among various stakeholders, which should be a lesson for the future.

Contaminated Sites from the Past – EPA Experience

M.A. Boyd

ICRP Committee 4
Radiation Protection Division, Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Washington, USA

In the United States, the Environmental Protection Agency (EPA) regulates the radiological cleanup of uranium mill tailings sites, some Department of Energy legacy sites within the U.S. nuclear weapons complex, and Superfund National Priorities List (NPL) sites. The approach to site remediation decisions, including the determination of cleanup levels, varies according to the enabling legislation granting EPA these authorities. Past practices that gave rise to many of the existing exposure situations at legacy sites were permissible before the advent of environmental cleanup legislation. The Uranium Mill Tailings Radiation Control Act of 1978 (UMTRCA) authorised EPA to set generally applicable radioactivity concentration standards for soil cleanup at inactive uranium mill sites and vicinity properties. For the other categories of sites mentioned above, remediation goals are typically based on not exceeding a target excess cancer risk range established under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA, also known as Superfund). EPA's regulations for cleaning up existing exposure situations achieve effective doses near, and sometimes well below, the doses at which planned exposures of the public are regulated in the U.S. Although the cleanup levels selected may differ from those adopted in other countries, recommendations of the International Commission on Radiological Protection are reflected in the exposure assessment methodologies used for establishing them.

Protection of the Environment in Existing Exposure Situation

D. Copplestone[a], C-M. Larsson[b], P. Strand[c]

[a]*ICRP Committee 5, Biological and Environmental Sciences, School of Natural Sciences, University of Stirling, Stirling, UK*
[b]*ICRP Committee 5 Chair, Australian Radiation Protection and Nuclear Safety Agency (ARPANSA), 38-40 Urunga Parade, Miranda NSW, Australia*
[c] *ICRP Committee 5, Statens strålevern, Grini næringspark 13, 1361 Østerås, Norway*

In *Publication 124,* the Commission described its approach to protection of the environment and how it should be applied. The report expanded on the Commission's objectives for environmental protection and how the Derived Consideration Reference Levels (DCRLs) apply within different exposure situations. DCRLs relate radiation effects to doses over and above their normal local background radiation levels and consider different potential pathways of exposure for animals and plants. In this presentation, we will describe how the DCRLs may be used within existing exposure situations, where control of the source is not in place, to better understand the potential impacts on animals and plants. In these circumstances, the Commission recommends that the aim should be to reduce exposures to levels that are within the DCRL bands (or even below, depending upon the potential cost/benefits) but with full consideration of the radiological and non-radiological consequences of doing so. Using examples, we will demonstrate how this may be achieved in practice bearing in mind the potential exposure of humans, animals and plants during and following any remediation attempted.

Eight Decades of ICRP Recommendations in Medicine: A Perspective

P.O. López

ICRP Committee 3
Pazmanitengasse, Vienna, Austria

Medicine has been intimately associated with radiation since the discovery of x rays in 1895; the first adverse effects from radiation were observed on medical staff and researchers. Consequently, in 1925, the first International Congress of Radiology considered the need of a protection committee, which was established at its second congress in Stockholm in 1928; today, it is known as the International Commission on Radiological Protection, ICRP. The first recommendations in 1928 were devoted to the protection of medical staff in the use of x rays for diagnosis and radium for radiotherapy. Later, ICRP paid attention to the protection of patients, starting in 1970 with *Publication 16* on Protection of the Patient in X-ray Diagnosis, followed by three documents in the broader area of radiation medicine: diagnostic radiology, radiation therapy and nuclear medicine. A major change was made at the end of the century by the introduction of a series of short publications, focussed on specific problems and addressed to specific medical groups. Since then, as many as 16 publications appeared on several issues, such as prevention of accidental exposure in radiotherapy, avoidance radiation injuries from interventional procedures, managing radiation dose in digital radiology and computed tomography, protection in paediatric radiology, and many others.

Current Issues in the Roles of Radiologists, Medical Physicists, Radiographers, and Manufacturers in Korea

K-H. Do

Departments of Radiology and Research Institute of Radiology, Asan Medical Center, University of Ulsan College of Medicine, Seoul, Korea

The radiation exposure from diagnostic medical imaging has increased in Korea. Each stakeholder plays a unique and complementary role for each patient-centred care system regarding radiological safety. Radiology and nuclear physician societies have a key role for radiation safety issues in Korea, including guidelines, accreditation, advocacy, scientific activity and education. Any medical radiation exposure must be justified and the examinations using ionising radiation must be optimised. The education of the referring physicians and radiologists is also important for justification. Medical physicists and radiographers have an important role for quality management and optimisation. Regulation is essential to control medical radiation exposure. Therefore, national organisations have made a significant effort to regulate and monitor medical radiation exposure using guidelines, accreditation, or even laws. Medical radiation exposure must be controlled and this could be achieved by continuous interests from health professionals and organisations.

Current Global and Korean Issues in Safety of Nuclear Medicine Procedures

H.C. Song

Department of Nuclear Medicine, Chonnam National University Hospital, Gwangju, Korea

In recent years, the management of patient doses in medical imaging has evolved as the concern about radiation exposure increases. Efforts and techniques to reduce the radiation doses are focused not only on the basis of patient safety but also the fundamentals of justification and optimisation in cooperation with international organisations such as ICRP, IAEA, and WHO. The Image Gently campaign in children and Image Wisely campaign in adults to lower radiation dose have been initiated in the USA. The EANM paediatric dosage card, North American consensus guidelines, and Nuclear Medicine Global Initiative all are recommending the administered activities of radiopharmaceuticals in children. Diagnostic reference levels (DRLs), which were developed mostly in Europe, might be an important tool to manage patient doses. In Korea, the overexposure to the radiation even by the use of medical imaging has become a public issue, especially after the nuclear accident in Fukushima. As a result, the Korean Nuclear Safety and Security Commission revised the technical standards for radiation safety management in medical fields. In parallel, DRLs for nuclear medicine procedures have been collected on a nation-wide scale. The notice of total effective dose from PET/CT for cancer screening has been mandatory since mid-November 2014.

Radiological Protection in Ion Beam Radiotherapy: A Practical Guidance for Clinical Use of New Technology

Y. Yonekura

ICRP Committee 3
National Institute of Radiological Sciences, Inage-ku, Chiba, Japan

Recently introduced new technologies in radiotherapy have improved patients' clinical outcome significantly. Ion beam radiotherapy, including proton and carbon ion beams, provides excellent dose distributions in targeted tumours with small effects to the surrounding healthy tissues. On the other hand, careful treatment planning is required in order to maximise the treatment efficiency and minimise the dose to the normal tissues. Radiation exposure from secondary neutrons and photons, particle fragments, and photons from activated materials should also be considered for radiological protection of the patient and medical staff. Appropriate maintenance is needed for the equipment and the air in the treatment room, which may be activated by the particle beam and its secondary radiation. This new treatment requires complex procedures and careful adjustment of parameters for every patient. Therefore, education and training for the personnel involved in the procedure are essential for both effective treatment and patient protection. ICRP provided recommendations for radiological protection in ion beam radiotherapy in *Publication 127*. Medical staff should be aware of the possible risk resulting from inappropriate use and control of the equipment. They should also consider the necessary procedures for patient protection when new technologies are introduced in clinical practice.

A Web-based ICRP Resource to Inform Healthcare Providers on the Risks and Benefits of Ionizing Radiation in Medicine

S. Demeter[a,b], K.E. Applegate[a,c], M. Perez[d]

[a]*ICRP Committee 3*
[b]*Section of Nuclear Medicine, Health Sciences Centre, Winnipeg, Manitoba, Canada*
[c]*Department of Radiology and Imaging Sciences Emory University School of Medicine, Atlanta, Georgia, USA*
[d]*Radiation Programme, Department of Public Health, Environmental and Social Determinants of Health (PHE), Cluster of Family, Women's and Children's Health (FWC), World Health Organization, 20, ave Appia, Switzerland*

This task consists of updating ICRP's web-based module "Radiation and Your Patient: A Guide for Medical Practitioners". The key elements of this task are: to clearly identify the target audience (such as healthcare providers with an emphasis on primary care); to review other reputable sources of information; and to succinctly publish what ICRP contributes to the discussion. There has been an exponential increase in the utilisation of diagnostic imaging and procedures as they are generally much less invasive than the traditional or historic diagnostic procedures. A "Q and A" format addressing practical and pragmatic topics has been chosen. Such topics include benefits and risks of ionising radiation in generic medical settings, as well as in the context of pregnant or breast feeding patients. In general, the benefits of medical imaging and related procedures far outweigh the potential risk associated with ionising radiation exposure. However, it is still important to ensure that the examinations are clinically justified, that the procedure is optimised to deliver the lowest dose commensurate with the medical purpose, and that consideration is given to diagnostic reference levels for particular classes of examinations.

Dose Coefficients of ICRP – Their Computational Development and Current Status

W.E. Bolch[a], N. Petoussi-Henss[b], F. Paquet[c], and J. Harrison[d]

[a]*ICRP Committee 2 and Chair, Task Group on Computational Phantoms and Radiation Transport, J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, USA*
[b]*ICRP Committee 2 and Chair, Task Group on Age Dependent Dose Coefficients for External Exposures to Environmental Sources, Helmholtz Zentrum München, German Research Center for Environmental Health, Neuherberg, Germany*
[c]*ICRP Committee 2 and Chair, Task Group on Dose Coefficients, Institute of Radiation Protection and Nuclear Safety (IRSN), Saint Paul Lez Durance Cedex, France*
[d]*ICRP Main Commission and Chair, ICRP Committee 2, Director, Centre for Radiation, Chemical and Environmental Hazards, Public Health England, Chilton, Didcot, Oxfordshire, UK*

Major current efforts within the International Commission on Radiological Protection (ICRP) Committee 2 are the development of dose coefficients for inhalation and ingestion of radionuclides, and those for exposure to environmental radiation fields. These efforts build upon fundamental changes in radiation and tissue weighting factors (*Publication 103*), radionuclide decay schemes (*Publication 107*), computational phantoms of the adult reference male and female (*Publication 110*), external dose coefficients for adult reference workers for idealised radiation fields (*Publication 116*), and models of radionuclide systemic biokinetics (*Publication 130*). In this presentation, we will review the overall computational framework for both external and internal dose coefficients. For the former, the computations entail the characterisation of environmental radionuclide distributions, the transport of radiation particles through that environment, and the tracking of energy deposition to the organs of the exposed individual. For the latter, the work entails assessment of organ self-dose and cross-dose from monoenergetic particle emissions (specific absorbed fraction), the absorbed dose per nuclear transformation (S value), the time-integrated activity of the radionuclide in source tissues (inhalation, ingestion, and systemic biokinetic models), and their numerical combination to yield the organ equivalent dose or effective dose per activity inhaled or ingested. Various challenges are reviewed that were not previously seen in the development of *Publication 30* dose coefficients – which were based upon much more simplified biokinetic models and computational phantoms. Progress toward the development of dose coefficients to members of the general public – adolescents, children, infants, and fetus – is also reviewed.

The Operational Quantities and New Approach by ICRU

A. Endo

ICRP Committee 2
Japan Atomic Energy Agency, Tokai-mura, Ibaraki, Japan
On behalf of the ICRU Report Committee 26 on Operational Radiation Protection Quantities for External Radiation

The protection quantities, equivalent dose in an organ or tissue and effective dose, were developed by ICRP to allow quantification of the extent of exposure of the human body to ionising radiation; they are to be used for the implementation of the limitation and optimisation principles. The body-related protection quantities are not measurable in practice. Therefore, International Commission on Radiation Units and Measurements (ICRU) developed a set of operational dose quantities for use in radiation measurements for external radiations that can assess the protection quantities. The current ICRU operational quantities were defined more than 30 years ago. The ICRU Report Committee 26 has examined the rationale for operational quantities taking into account the changes in the definitions of the protection quantities in the ICRP 2007 Recommendations. The considerations have included the range of types and energies of particles contributing to doses of workers and members of the public. The Committee has investigated a set of alternative definitions for operational quantities different to the existing quantities. The major change to the currently favoured set of quantities is the redefinition of the operational quantities for area monitoring, from being based on doses at a point in the ICRU sphere to being based on particle fluence and the relationship to the protection quantities, effective dose, and equivalent dose to the lens of the eye and local skin.

The Reference Phantoms: Voxel vs. Polygon

C.H. Kim[b,c], Y.S. Yeom[c], T.T. Nguyen[c], Z.J. Wang[c], H.S. Kim[c], M.C. Han[c], J.K. Lee[a,c], M. Zankl[d], N. Petoussi-Henss[b,d], W.E. Bolch[b,e], C. Lee[f], M.S. Chung[g]

[a]*ICRP Main Commission*
[b]*ICRP Committee 2*
[c]*Department of Nuclear Engineering, Hanyang University, Seoul, Korea*
[d]*Research Unit Medical Radiation Physics and Diagnostics, Helmholtz Zentrum München Deutsches Forschungszentrum für Gesundheit und Umwelt (GmbH), Neuherberg, Germany*
[e]*J. Crayton Pruitt Family Department of Biomedical Engineering, University of Florida, Gainesville, Florida, USA*
[f]*Division of Cancer Epidemiology & Genetics, National Cancer Institute, Bethesda, Maryland, USA*
[g]*Department of Anatomy, Ajou University School of Medicine, Suwon, Korea*

The ICRP reference male and female adult phantoms, described in *Publication 110*, are voxel phantoms based on whole body computed tomography scans of a male and female patient, respectively. The voxel in-plane resolution and the slice thickness were of the order of a few mm; thus, smaller tissues, like the lens of the eye, skin or the walls of some organs, could not be properly segmented. The calculated doses for these tissues have therefore some limitations, particularly for weakly-penetrating radiation. Similarly, the *Publication 110* phantoms cannot represent micron-thick target tissues in respiratory and alimentary tract regions. Consequently, separate stylised models have been used to represent these tissues for the calculation of the ICRP reference dose coefficients. In this context, ICRP Committee 2 recently initiated a research project to convert the *Publication 110* phantoms into polygonal-mesh format. The ultimate goal of the conversion project is to produce an exact replica of the *Publication 110* phantoms in a high-quality polygonal-mesh format, including all source and target regions, even those of the alimentary and respiratory tract organs with micron resolution. It is expected that the converted phantoms would lead to the same, or very similar, dose coefficients as the *Publication 110* reference phantoms for penetrating radiation. At the same time, it would provide more accurate dose coefficients for weakly penetrating radiation and small tissues. In addition, the reference phantoms in polygonal-mesh format would be easily deformable and could serve as a starting point to create phantoms of various postures to be used, for example, in accidental dose calculations. In this presentation, we will report the current progress of the phantom conversion project and discuss its significance for the ICRP dose calculations and radiation protection dosimetry in general.

Assessment and Interpretation of Internal Dose: Uncertainty and Variability

F. Paquet[a], J. Harrison[b]

[a]*ICRP Committee 2, Institute of Radiation Protection and Nuclear Safety (IRSN), BP3, 13115 Saint Paul lez Durance, Cedex, France*
[b]*ICRP Committee 2 Chair, Public Health England, Centre for Radiation, Chemical and Environmental Hazards, Chilton, Didcot, Oxfordshire, UK*

Internal doses are calculated on the basis of knowledge of intakes and/or measurements of activity in bioassay samples, using biokinetic and dosimetric models. These models describe the behaviour of the radionuclides after ingestion, inhalation and absorption to the blood, and the absorption of the energy resulting from their nuclear transformations. They are intended to be used mainly for the purpose of radiological protection; that is, optimisation and demonstration of compliance with dose limits. These models and parameter values are fixed by convention and are not subject to uncertainty. During the past few years, the International Commission on Radiological Protection (ICRP) has devoted a considerable amount of effort in the revision and improvement of models to make them more physiologically realistic. ICRP models are now so sophisticated that they can also be used to calculate organ and tissue absorbed doses for scientific purposes, and in many other areas, including toxicology, pharmacology and medicine. In these specific cases, uncertainties in parameters and variability between individuals need to be taken into account.

The Use of Effective Dose

J. Harrison

ICRP Committee 2 Chair
Public Health England, Centre for Radiation, Chemical and Environmental Hazards, Chilton, Didcot, Oxon, UK

Effective dose was introduced in the International Commission on Radiological Protection (ICRP) 1977 Recommendations, at which time the overriding concern was the control of occupational exposures. As a whole body dose, it provided the necessary metric for the practical implementation of the principles of optimisation and limitation. It presents an elegant solution to the requirement for a single quantity that enables the summation of all radiation exposures, including both external and internal exposures. The concept underlying effective dose has remained essentially unchanged since the 1990 Recommendations until the 2007 Recommendations. However, application of effective dose has been extended to protection of members of the public of all ages, including in utero exposures of the embryo and fetus. Particularly problematic is the use of effective dose in the assessment of medical exposures of patient populations of different ages and where the requirement is for a measure of risk to individuals. While doses may be calculated with reasonable reliability down to low levels, the associated risks implied by the linear-no-threshold dose-response model are uncertain. ICRP will publish advice on the use of effective dose for all situations of exposure, addressing issues including control of in utero exposures and risk estimation in medical applications.

Dosimetry for Animals and Plants – Contending Biota Diversity

A. Ulanovsky

ICRP Committee 5
Institute for Radiation Protection, Helmholtz Zentrum Munich – German Research Center for Environmental Health, Ingolstädter Landstraße 1, Germany

Diversity of living organisms and of their environmental radiation exposure conditions is a special challenge for non-human dosimetry. To contend with this diversity, ICRP (*a*) sets up points of reference by providing dose conversion coefficients for reference entities (known as the ICRP Reference Animals and Plants) and (*b*) uses dosimetric models which pragmatically assume simple body shapes with uniform composition and density, homogeneous internal contamination, a limited set of idealised external radiation sources, and truncation of the radioactive decay chains. This pragmatic methodology has been further developed and systematically extended. Significant methodological changes include: transition to the contemporary ICRP radionuclide database, a new extended approach for assessing doses of external exposure for terrestrial animals, assessment-specific consideration of radioactive progeny's contribution to dose coefficients of parent nuclides, and the use of generalised allometric relationships in estimation of biokinetic or metabolic parameters. The new methodological developments resulted in a revision of the dose conversion coefficients for the Reference Animals and Plants. Tables of the dose coefficients have now been complemented by a web-based software tool, which can be used to calculate user-specific dose conversion coefficients for an organism of arbitrary mass and shape, located at user-defined height above the ground and for arbitrary radionuclide and its radioactive progeny.

New ICRP *Publication 131*: Stem Cell Biology with Respect to Carcinogenesis Aspects of Radiological Protection

O. Niwa[a], M.H. Barcellos-Hoff[b], R.K. Globus[c], J. Harrison[d], J.H. Hendry[e], P. Jacob[f], M.T. Martin[g], T.M. Seed[h], J.W. Shay[i], M.D. Story[i], K. Suzuki[j], S. Yamashita[j]

[a]*ICRP Main Commission, Fukushima Medical University, Fukushima, Japan*
[b]*Radiation Oncology and Cell Biology, New York University School of Medicine, New York, USA*
[c]*Bone and Signalling Laboratory, Space Biosciences Research Branch, NASA Ames Research Center, CA, USA*
[d]*ICRP Committee 2 Chair, Centre for Radiation, Chemical and Environmental Hazards, Health Protection Directorate, Public Health England, Chilton, Oxon, UK*
[e]*Christie Medical Physics and Bioengineering, Christie Hospital NHS Foundation Trust and University of Manchester, UK*
[f]*Helmholtz Zentrum Munchen, German Research Center for Environmental Health, Neuherberg, Germany*
[g]*Laboratoire de Genomique et Radiobiologie de la Kertinopoiese, CEA, Evry, France*
[h]*Maple Avenue, Bethesda, USA*
[i]*Radiation Oncology, Simmons Cancer Center, University of Texas, Southwestern Medical Center, Dallas, Texas, USA*
[j]*Molecular Medicine, Graduate School of Biomedical Sciences, Nagasaki University, Japan*

Current knowledge of stem cell characteristics, maintenance and renewal, evolution with age, location in stem cell “niches”, and radiosensitivity to acute and protracted exposures, is reviewed regarding haematopoietic tissue, mammary gland, thyroid, digestive tract, lung, skin, and bone. This foundation is used to provide a biological insight to protection issues such as the linear-no-threshold and relative risk models, cancer risk differences among tissues, dose-rate effects, and changes in the risk of radiation carcinogenesis by age at exposure and attained age. The identity of the target cells for carcinogenesis continues to point to the more-primitive and mostly-quiescent stem-cell population, able to accumulate the protracted sequence of mutations necessary to result in malignancy. Several biological processes could contribute in protecting stem cells from mutation accumulation: (1) accurate DNA repair, (2) rapid induced death of injured stem cells, (3) retention of the intact parental DNA-template strand during divisions in some tissues, so that mutations are passed to the daughter differentiating cells, and (4) stem cell competition, whereby undamaged stem cells outcompete damaged stem cells for residence in the vital niche. DNA repair operates mainly within a few days after irradiation, while stem cell competition requires weeks or many months depending on the tissue type.

Radiation-related Risks of Non-cancer Outcomes in the Atomic-bomb Survivors

K. Ozasa

Department of Epidemiology, Radiation Effects Research Foundation, Minami-ku, Hiroshima, Japan

Risks of non-cancer outcomes after exposure to atomic-bomb radiation have been evaluated among the Life Span Study (LSS) cohort and among its subcohort, the Adult Health Study (AHS). Information regarding non-cancer outcomes in the LSS is obtained only from death certificates. In the AHS, members are clinically examined for their health status biennially, yet the analyses have usually been limited to the participants within a specific time period. The results of these various radiation risk evaluations have depended on the epidemiological advantages and disadvantages inherent in each. Appropriate interpretation of the differences seen in the results of LSS and AHS analyses is therefore necessary. Pathogenesis of non-cancer diseases in Japan has changed over the long follow-up period since the devastated post-war era until the recent highly-developed era. The health status of the atomic-bomb survivors may be associated with impaired socio-economic status after the bombings. Radiation-related cardiovascular disease risk appeared to increase compared to infection and hypertension disorders in the past. Risk of atherosclerotic disorders has recently been described, but these observations may be affected by disease definition. The risk of non-cancer respiratory diseases also appeared to increase in various dose-response shapes during the follow-up period.

Dose Rate Effects in Radiation Biology and Radiation Protection

W. Rühm

ICRP Committee 1
Helmholtz Center Munich, Deutsches Forschungszentrum für Gesundheit und Umwelt (GmbH), Ingolstädter Landstr. 1, Neuherberg, Germany

The risk associated with the exposure to ionising radiation has been a major issue for ICRP since its foundation in 1928. There has been knowledge on the effects on human health for whole body doses above about 100 mGy. However, effects associated with lower doses are still intensively being debated. The current radiation protection approach proposed by ICRP for workers and the public is largely based on analyses of high-dose and high-dose-rate studies, such as the Japanese Life Span Study on atomic bomb survivors. The risk coefficients obtained from these studies are then reduced by the Dose and Dose Rate Effectiveness Factor (DDREF) to account for the assumed lower effectiveness of low-dose and low-dose-rate exposures. In its latest Recommendations, ICRP continues to propose the use of a factor value of 2 while other international institutions suggest the use of different values or even to abandon the factor. This presentation summarises the current status of discussion and highlights issues that might be relevant to re-assess the DDREF.

Evidence for Variation in Human Radiosensitivity and its Potential Impact on Radiological Protection

S.D. Bouffler

ICRP Committee 1
Radiation Effects Department, Centre for Radiation, Chemical and Environmental Hazards, Public Health England, UK

Radiological protection standards generally assume all members of the population are equally sensitive to the adverse health effects associated with radiation exposure. It has become very clear over recent years that genetic and lifestyle factors can play important roles in the susceptibility of individuals to a range of diseases; thus, the same might apply to radiation-associated disease. There is evidence accumulating from studies at many levels of biological organisation – cells, experimental organisms and humans – that a range of radiosensitivity exists in the populations. A key factor required to exploit such knowledge for radiological protection purposes will be the availability of robust and accurate ways to assess the sensitivity of an individual or population sub-group. In addition, there will need to be careful consideration of the ethical aspects relating to use of individual sensitivity information. These ethical considerations are very likely to be exposure context-dependent, and require careful risk-benefit balance consideration before practical application.

Analysis of Individual Difference of Radiosensitivity using Genome-editing Technique

S. Matsuura[a], E. Royba[a], S.N. Akutsu[a], H. Yanagihara[a], H. Ochiai[b], Y. Kudo[c], S. Tashiro[d], T. Miyamoto[a]

[a]*Department of Genetics and Cell Biology, Research Institute for Radiation Biology and Medicine (RIRBM), Hiroshima University, Hiroshima, Japan*
[b]*Research Center for the Mathematics on Chromatin Dynamics, Hiroshima University, Higashi-Hiroshima, Japan*
[c]*Department of Obstetrics and Gynecology, Grad. Sch. Biomed. Sci., Hiroshima University, Hiroshima, Japan*
[d]*Department of Cellular Biology, RIRBM, Hiroshima University, Hiroshima, Japan*

Current standards for radiological protection are applied uniformly to the public. However, the radiosensitivity of individual people can vary; this might depend on the nucleotide variants on the individual's DNA repair genes. To verify that these variants indeed result in a difference of radiosensitivity, it is useful to introduce such nucleotide variants into cultured human cells and evaluate their radiosensitivity. This will allow for a precise analysis of the effect of candidate nucleotide variants on individual radiosensitivity, independently of the diverse genetic background. However, having efficient gene targeting of cultured human cells has been difficult due to the low frequency of homologous recombination repair. Therefore, development of artificial nucleases enabled efficient homologous recombination-mediated genome editing to be performed in cultured human cells. Recently, we developed a novel genome editing strategy, called "TALEN-mediated two-step single-base-pair editing" and biallelically introduced a nucleotide variant associated with chromosomal instability into cultured human cells. The single-base-pair editing technique is now used to generate human model cells carrying the candidate nucleotide variants on DNA repair genes and to investigate their radiosensitivity.

The Ethical Foundations of the Radiological Protection System

K.W. Cho

ICRP Committee 4
Korea Institute of Nuclear Safety, Daejeon, Korea

The International Commission on Radiological Protection (ICRP) has established Task Group 94 under Committee 4 to develop a report on the ethical foundations of the system of radiological protection. The report is to consolidate the basis of ICRP recommendations, to improve the understanding of the system, and to provide a basis for communication on radiation risk and its perception. Through large series of workshops organised by the Commission in cooperation with the International Radiation Protection Association and its Associate Societies involving radiation protection professionals and specialists of ethics around the world, Task Group 94 has identified the key ethical and social values underpinning the system of radiological protection. The purpose of eliciting the ethical principles and values of radiological protection system is not only to clarify the rationale for recommendations made by the Commission, but also to assist in discussions related to its practical implementation. A clear understanding of the ethical principles will help to resolve dilemmas caused by potential conflicts in actions that might be considered, or decisions that must be made. Task Group 94 is developing case studies for various radiological protection practices such as medical, worker and nuclear safety, waste management, accidents, and environmental protection.

The Focal Role of Tolerability and Reasonableness in the Radiological Protection System

T. Schneider

Nuclear Evaluation Protection Centre (CEPN), Fontenay-aux-Roses, France

The concepts of tolerability and reasonableness are at the core of ICRP system of radiological protection. Tolerability allows one to define boundaries for the implementation of ICRP principles, while reasonableness contributes to finding an adequate level of protection, taking into account economic and societal aspects given the prevailing circumstances. In the 1970s and 1980s, attempts to find the base of tolerability (risk comparison) and reasonableness (cost-benefit analysis) failed. In practice, searching for these concepts will never end: in order to make a wise decision, it will always depend on the prevailing circumstances, knowledge, and experience. The presentation will discuss the constituents of tolerability and reasonableness, which would improve the implementation of the radiation protection system. The main objectives are to: do more good than harm (beneficience); avoid unnecessary risk (prudence); seek a fair distribution of exposures (justice); and, treat people with respect (dignity). It will also emphasise the increasing role of stakeholder engagement in the quest for tolerable and reasonable since ICRP *Publication 103*.

The Ethics of Radiological Risk Governance – The Justice of Justification as a Central Concern

G. Meskens

Science & Technology Studies Unit, SCK CEN, Mol, Belgium & Centre for Ethics and Value Inquiry, Faculty of Arts and Philosophy, University of Ghent, Belgium

Due to the specific character of radiological risk, judgements on whether or not the use of nuclear technology would be justified in society have to take into account knowledge-related uncertainties and value pluralism. The justice of justification, thus, not only informs the right of the potentially affected to participate in decision making, but it also implies the responsibility of concerned actors to give account of the way they rationalise their interests and beliefs in knowledge generation and decision making. From this perspective, the presentation argues that there is a need for a 'performative' understanding of ethics in order to give ethical values or virtues a practical meaning in a socio-political context. Consequently, it proposes the concepts of 'reflexivity as an ethical experience' and 'intellectual solidarity as an ethical commitment' and elaborates on the way they could inform the methods of justification, optimisation, and the ratio of dose limitation in radiological risk governance.

The Ethical Foundations of Environmental Radiological Protection

D.H. Oughton

ICRP Committee 4
Centre for Environmental Radioactivity (CERAD), Norwegian University of Life Sciences, Aas, Norway

Assessing the potential ecological impact of ionising radiation raises a number of ethical questions. These include fundamental questions such as what exactly constitutes harming the environment and how the environment should be valued, as well as links to political protection principles such as sustainability and biodiversity. Starting from developments within ecological risk assessment, the paper will summarise some of the ethical issues concerning the protection of the environment from radiation. The first part gives an overview of different philosophical and cultural worldviews on valuing the environment in a context of radiation risk. The second part addresses some recent challenges to proposed environmental protection frameworks, including practical applications following the Chernobyl and Fukushima accidents, and scientific developments such as the ecosystem approach. The final part of the paper offers some recommendations on how ethical evaluation can aid in producing a robust and transparent approach to protection of the environment. In conclusion, there is a need for a holistic evaluation of the environmental impacts of ionising radiation that not only considers the direct consequences on the health of humans and non-human species, but also the more complex social, ethical, and economic consequences of both human and non-human exposures.

Are the Core Values of the Radiological Protection System Shared across Cultures?

F. Zölzer

Department of Radiology, Toxicology and Civil Protection, Faculty of Health and Social Studies, University of South Bohemia, České Budějovice, Czech Republic

In spite of the ongoing globalisation in many fields, the ethics of radiation protection has long been discussed almost exclusively in terms of "Western" moral philosophy concepts such as utilitarianism or deontology. A cross-cultural discourse in this field is only beginning. Beauchamp and Childress in their "Principles of Biomedical Ethics" have suggested that there exists a "common morality" which is "not relative to cultures or individuals, because it transcends both". They propose four cross-culturally valid principles for decision making in medicine: respect for autonomy, non-maleficence, beneficence, and justice. A similar approach is being developed by the ICRP Task Group 94 on "Ethics of Radiological Protection". Here, the core values are: human dignity, beneficence/non-maleficence, prudence and justice. Other values could be added, such as consideration for the interests of society as a whole or the interests of future generations, or procedural values such as transparency and accountability; there will be a brief discussion on how they relate to the basic four. The main question to be addressed here, however, is whether the proposed core values are indeed part of a "common morality". This, it will be argued, cannot be decided by a global opinion poll, but has to be based on an analysis of the written and oral traditions which have provided ethical orientation throughout history and are still considered seminal by a majority of people. It turns out that there are indeed many commonalities across cultures and the concept of globally shared core values for the radiological protection system is not hopelessly idealistic.

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