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International Commission on Radiological Protection – recent publications, current initiatives and future work

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Abstract

In 2007, after almost a decade of development and worldwide, open consultation, the International Commission on Radiological Protection (ICRP) published its latest fundamental recommendations describing the overall system of radiological protection in the 2007 Recommendations of the International Commission on Radiological Protection. These replaced the 1990 Recommendations of ICRP published almost two decades earlier. Since then ICRP has focused primarily on developing publications that support or further elaborate elements of the system of radiological protection as described in the 2007 Recommendations. This paper describes these publications, as well as ongoing and planned future efforts with the same objective.

Introduction

The International Commission on Radiological Protection (ICRP) is an independent, international organization that advances for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation.

ICRP was established in 1928 by the International Society of Radiology (ISR) to respond to growing concerns about the effects of ionizing radiation being observed in the medical community. At the time it was called the International X-ray and Radium Protection Committee, but was restructured to better take account of uses of radiation outside the medical area and given its present name in 1950.

ICRP is a Registered Charity (a “not-for-profit organisation) in the United Kingdom, and has a Scientific Secretariat in Ottawa, Canada.

In preparing its recommendations, ICRP considers the fundamental principles and quantitative bases upon which appropriate radiation protection measures can be established, while leaving to the various national protection bodies the responsibility of formulating the specific advice, codes of practice, or regulations that are best suited to the needs of their individual countries.

ICRP offers its recommendations to regulatory and advisory agencies and provides advice the intended to be of help to management and professional staff with responsibilities for radiological protection. Although ICRP itself has no formal power to

impose its recommendations, in fact legislation in most countries adheres closely to ICRP recommendations. In addition, the International Atomic Energy Agency (IAEA) International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (commonly referred to as "the BSS") is based heavily on ICRP recommendations, and the International Labour Organisation (ILO) Convention 115, Radiation Protection Convention, General Observation 1992, refers specifically to the recommendations of ICRP. Effectively, ICRP recommendations form the basis of radiological protection practice, programmes, regulations, and international standards and guidance worldwide.

Originally, ICRP published its recommendations and advice as papers in various scientific journals in the fields of medicine and physics. Since 1959, ICRP has its own series of publications, since 1977 in the shape of a scientific journal, the Annals of the ICRP, which is published Elsevier Science.

ICRP has published well over one hundred publications on all aspects of radiological protection. Most address a particular area within radiological protection, but a handful of publications, the so-called fundamental recommendations, each describe the overall system of radiological protection. The system of radiological protection has been developed by ICRP based on (i) the current understanding of the science of radiation exposures and effects and (ii) value judgements. These value judgements take into account societal expectations, ethics, and experience gained in application of the system.

The 1990 Recommendations of ICRP form the basis of the current IAEA BSS, and are also the foundation of most radiological protection practices, programmes and regulations worldwide. The 2007 Recommendations recently replaced the 1990 Recommendations. They are the result of nearly a decade of development and several major worldwide public consultations. They update, consolidate, and develop additional guidance on the control of exposure from radiation sources issued since 1990, and they reflect a more up-to-date understanding of the science behind radiological protection and evolving societal expectations.

The 2007 Recommendations of ICRP

Although a complete review of the 2007 Recommendations (ICRP *Publication 103*) is beyond the scope of this paper, it is important to recall that all exposures are divided among three categories of exposure and three exposure situations.

Three categories of exposure described in the system of radiological protection are: occupational exposures, public exposures, and medical exposures of patients (and comforters, carers, and volunteers in research).

The system of radiological protection also recognises three types of exposure situations, intended to cover the entire range of exposure situations. Planned exposure situations involve the planned introduction and operation of sources. Emergency exposure situations are unexpected situations such as those that may occur during the operation of a planned situation, or from a malicious act, requiring urgent attention. Existing exposure situations are situations that already exist when a decision on control has to be taken, such as those caused by natural background radiation. These exposure situations replace the previous categorisation into practices and interventions, although in most cases planned exposure situations are analogous to circumstances in which one

is undertaking a practice, and emergency and existing exposure situations are similar to situations requiring an intervention.

For more information on the 2007 Recommendations of ICRP the reader is referred to another paper prepared for this congress by the same author titled "ICRP 103 and Beyond".

Publications since the 2007 Recommendations of ICRP

At the time of writing this paper, ICRP has released seven ICRP publications (formally ten issues) of the Annals of the ICRP, and two additional publications are in press. These are listed in Table 1. In addition, a report titled "Reference Data for the Validation of Doses from Cosmic-Radiation Exposure of Aircraft Crew", jointly prepared by the International Commission on Radiation Units and Measurements (ICRU) and ICRP, is in press and will be published as an ICRU report by Oxford University Press.

Table 1. ICRP Publication to Date since the 2007 Recommendations of ICRP.

ICRP Publication	Title	Ann. ICRP Volume and Issue
104	Scope of Radiological Protection Control Measures	37 (5)
105	Radiological Protection in Medicine	37 (6)
106	Radiation Dose to Patients from Radiopharmaceuticals	38 (1-2)
107	Nuclear Decay Data for Dosimetric Calculations	38 (3)
108	Environmental Protection - the Concept and Use of Reference Animals and Plants	38 (4-6)
109	Application of the Commission's Recommendations for the Protection of People in Emergency Exposure Situations *	39 (1)
110	Adult Reference Computational Phantoms	39 (2)
In press	Application of the Commission's Recommendations to the Protection of People Living in Long Term Contaminated Areas after a Nuclear Accident or a Radiation Emergency	
In press	Avoidance of Unintended Exposure in Radiotherapy with New Technologies	

* ICRP *Publication 109* also includes the article "The History of ICRP and the Evolution of its Policies" by Clarke and Valentin.

These publications support and further elaborate elements of the system of radiological protection as described in the 2007 Recommendations, and most fall into one of two broad categories: those that elaborate on specific exposure categories (occupational, public and medical) or situations (planned, existing, and emergency), and those that provide detailed technical information necessary for the implementation of the system of radiological protection.

Two that do not fit neatly into this categorisation are ICRP *Publication 104* and ICRP *Publication 108*. They are overarching documents which consider, in principle, all exposure categories and situations.

Recent ICRP Publications Elaborating on Specific Exposure Categories and Situations

One of the first publications following the 2007 Recommendations was ICRP *Publication 105* on Radiological Protection in Medicine. This publication describes the application of the system of radiological protection for medical exposures, an exposure category quite different from occupational and public exposures by virtue of the fact that most of the time, most of the benefit and the detriment apply to a single individual: the patient. In the other two exposure categories, typically one group receives most of the detriment (e.g. the workers in a facility), while another group receives most of the benefit (e.g. the public at large receiving electrical power).

Two publications each examine one of the three exposure situations: ICRP *Publication 109* examines emergency exposure situations, and the ICRP publication in press "Application of the Commission's Recommendations to the Protection of People Living in Long Term Contaminated Areas after a Nuclear Accident or a Radiation Emergency" examines the system of radiological protection as applied to existing exposure situations.

These three publications elaborate upon the system of radiological protection as applied in most circumstances. The first covers medical exposures which occur, by definition, only within planned exposure situations. The second covers occupational and public exposures in emergency situations. The third covers public exposures in existing exposure situations, which ICRP considers as the only valid exposure category in that exposure situation. The exposures not within the scope of these three documents are occupational and public exposures in planned exposure situations.

As well, the ICRP Publication in press "Avoidance of Unintended Exposure in Radiotherapy with New Technologies" further elaborates on aspects of radiological protection with respect to medical exposures, focusing specifically on the use of certain new radiotherapy technologies.

Recent ICRP Publications Providing Supporting Information

Within this category is a recent publication specific to radiological protection in medicine. ICRP *Publication 106* is the third amendment to ICRP *Publication 53*, Radiation Dose to Patients from Radiopharmaceuticals. This is part of ongoing work to provide up-to-date biokinetic and dosimetric models for radiopharmaceuticals along with tabulated results giving absorbed doses to the various organs over time per unit activity administered.

Also within this category are two recent publications related to the calculation of protection quantities. Although the concepts of effective and equivalent dose have not changed in the 2007 Recommendations of ICRP, the methods and some of the parameters used to calculate these protection quantities have been updated. Revised radiation and tissue weighting factors were published in the 2007 Recommendations. In addition, the 2007 Recommendations specified that doses should now be calculated using voxel (volume element) phantoms. ICRP *Publication 110* provides the first of these voxel phantoms: those for the reference adult male and female. ICRP *Publication 107* provides updated nuclear decay data for dosimetric calculations, replacing ICRP *Publication 38*, Radionuclide Transformations: Energy and Intensity of Emissions. These publications are necessary steps towards developing dose conversion coefficients compatible with the full implementation of the 2007 Recommendations.

ICRP *Publication 104*: Scope of Radiological Protection Control Measures

In principle the system of radiological protection applies to all exposures to ionizing radiation. However, in practice the measures undertaken to control these exposures must be limited based on practical considerations. ICRP *Publication 104* discusses the scope of radiological protection control measures, and describes certain tools (e.g. exemption, exclusion and clearance) that can be used to manage the scope.

ICRP *Publication 108*: Environmental Protection – the Concept and Use of Reference Animals and Plants

In the past, ICRP concerned itself with the environment primarily with regard to the transfer of radionuclides through it because this directly affects the radiological protection of human beings. In the 1990 Recommendations ICRP stated that "the standard of environmental control needed to protect man ... will ensure that other species are not put at risk. Occasionally, individual members of non-human species might be harmed, but not to the extent of endangering whole species or creating imbalance between species."

However, in its 2007 Recommendations, ICRP acknowledges that that it is now necessary to demonstrate, directly and explicitly, that the environment is being protected. Therefore, it is necessary to develop a clearer framework to assess the relationships between exposure and dose, and between dose and effect, and the consequences of such effects, for non-human species, on a common scientific basis.

To this end, ICRP *Publication 108* sets out some high-level ambitions with regard to environmental protection. To aid in demonstrating whether these ambitions are being achieved, and help optimise the level of effort that might be expended on environmental protection, and ICRP has developed a set of Reference Animals and Plants (RAPs) and derived consideration reference levels (DCRLs). ICRP does not propose the application of dose limits to Reference Animals and Plants.

Current Initiatives and Future Work

The current plan of work for ICRP includes initiatives in several areas. Of significant interest is work on elaborating on the application of the system of radiological protection for radon. ICRP is also continuing efforts to: examine emerging scientific results on radiation effects and how they may impact the system of radiological protection; support calculation of protection quantities (effective and equivalent dose) in accordance with the 2007 Recommendations; and further elaborate on the system of radiological protection in medicine, other specific circumstances, and with respect to protection of the environment.

Radon

In November 2009 ICRP issued a Statement on Radon. The intention is to publish this Statement in the Annals of the ICRP with an accompanying report on assessment of lung cancer risk from radon, after undertaking a public consultation on the two documents together.

The statement reaffirms that, for planned exposure situations, any workers' exposure to radon incurred as a result of their work, however small, shall be considered as occupational exposure. Paragraph 178 of ICRP *Publication 103* defines occupational

exposure is as all radiation exposure of workers incurred as a result of their work. It is noted the conventional definition of occupational exposure to any hazardous agent includes all exposures at work, regardless of their source. However, because of the ubiquity of radiation, the direct application of this definition to radiation would mean that all workers should be subject to a regime of radiological protection. Therefore the use of 'occupational exposures' is limited to radiation exposures incurred at work as a result of situations that can reasonably be regarded as being the responsibility of the operating management.

The statement, which will be supported by an accompanying report on assessment of lung cancer risk from radon, introduces a new recommended detriment-adjusted nominal risk coefficient for a population of all ages of $8x10^{-10}$ per Bq h m^{-3} for exposure to radon-222 gas in equilibrium with its progeny (i.e. $5x10^{-4}$ WLM^{-1}). The statement notes that this is consistent with other comprehensive estimates including that submitted to the United Nations General Assembly by UNSCEAR.

In addition, ICRP is working on a publication which will provide more specific recommendations for applying the system of radiological protection to radon exposure in various circumstances.

Radiation Effects

The system of radiological protection is based both on science (primarily what is known about the effects of radiation exposure) and value judgements. Therefore, a key component of the work of ICRP is staying current on the latest scientific findings on radiation effects, in particular to evaluate how they might influence the system of radiological protection. Work on assessing the lung cancer risk from radon has already been mentioned. This is only one part of an effort to review the state of knowledge of the health effects of exposure to alpha radiation. Two other groups within ICRP are also examining stem cell biology in relation to radiation effects, and tissue reactions and other non-cancer effects of radiation. The latter group is most interested in effects on the lens of the eye (where evidence seems to point to a threshold for radiation induced cataracts much lower than previously thought), and cardio-vascular effects (which are well documented at doses generally only important for patients undergoing radiation therapy, but for which there may be some emerging evidence of effects at doses approaching the upper end of the occupational dose limits).

Dose Calculation

As mentioned previously the system of radiological protection now recommends that effective and equivalent dose be calculated using more up-to-date radiation and tissue weighting factors, and using voxel (volume element) phantoms. In addition ICRP *Publication 107* provides new radionuclide transformation data, and there are relatively recent modifications to biokinetic models to be taken into account.

ICRP *Publication 110* provides the first voxel phantoms (for the reference adult male and female), but much work remains to develop similar voxel phantoms for paediatric, foetal, and pregnant female voxel phantoms. These phantoms, along with other factors, will then be used to calculate dose coefficients for external and internal exposure for workers and the public.

Radiological Protection in Medicine

When ICRP was created more than eighty years ago, the focus was on radiological protection of medical practitioners and researchers. Today ICRP still has a focus on radiological protection in medicine, and continues to provide recommendations on protection of practitioners, but radiological protection of patients has become a significant issue. Over the last decade this emphasis on radiological protection of patients has grown considerably given the rapid increases in worldwide patient doses from medical imaging.

Currently under way within ICRP are efforts related to the radiological protection of both patients and practitioners related to fluoroscopically guided procedures, including a specific report aimed at cardiologists. Another effort is related to radiological protection in paediatric diagnostic radiology.

ICRP is also working on recommendations on radiological protection education and training for healthcare staff and students, and recommendations that take into account consideration of the possibility of secondary cancers related to some modern radiotherapy techniques.

Further Elaboration of the System of radiological protection

Having broadly described on the system of radiological protection in ICRP *Publication 103*, and elaborated on some general circumstances of exposure in ICRP *Publication 105*, ICRP *Publication 109*, and the ICRP publication in press titled "Application of the Commission's Recommendations to the Protection of People Living in Long Term Contaminated Areas after a Nuclear Accident or a Radiation Emergency", ICRP is now planning a series of publications that further elaborate the system of radiological protection in more specific circumstances. These include reports that will focus on radiological protection related to: aircrew and space crew; naturally occurring radioactive materials; geologic waste disposal; deliberate exposure for security and legal requirements; and, the proper use of effective dose.

Radiological Protection of the Environment

As described previously ICRP *Publication 103* formally introduced explicit protection of the environment into the system of radiological protection, and ICRP *Publication 108* set out some high-level ambitions and a set of Reference Animals and Plants (RAPs) and derived consideration reference levels (DCRLs).

Current efforts in this area are focusing on a broader view of how the protection of humans and non-human biota are integrated into the system of radiological protection, and more specific recommendations on dosimetry for RAPs. The latter includes looking at questions related to radiation weighting factors for non-human biota, transfer values in environmental modelling.

Summary and Conclusion

The system of radiological protection described in the 2007 Recommendations (ICRP *Publication 103*) is an evolutionary change from that described in the 1990 Recommendations (ICRP *Publication 60*). This evolution is necessary in order for the system of radiological protection to remain current with respect to our evolving understanding of the relevant scientific findings, and also to continue to reflect current

societal norms. For example, the revised radiation and tissue weighting factors reflect updated scientific knowledge, while a greater emphasis on environmental protection reflects a heightened social awareness of the importance of this area. As well, practical application of the system can point out areas for improvement.

However, as the system of radiological protection in general evolves so must the supporting recommendations and tools. As well, the recommendations must continue to take into account novel uses of radiation in medicine and other fields to help ensure an adequate level of safety under all circumstances.

In the five to ten years leading up to publication of the 2007 Recommendations much of the focus of ICRP was on development of this evolutionary update to the system of radiological protection. Barring revolutionary new findings that demand a rapid overhaul of the system, for the next decade or so ICRP will focus on refining and further elaborating the system of radiological protection as set out in 2007, always with an eye on emerging science, evolving social norms, and novel uses of radiation.

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The Euratom Programme of Research and Training on Low Doses of Radiation

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Abstract
The Euratom programme of research and training on the risks associated with low doses of radiation will be closely aligned to priorities identified in the Strategic Research Agenda (SRA) of MELODI and the Transition Research Agenda (TRA) to be implemented through the project DoReMi funded as part of the 7th Euratom Framework Programme. These research agendas are aimed at integrating the European research effort on low dose, at opening this effort to the wider scientific community and at promoting and facilitating the sustainable integration of key research institutions in European Member States.

Introduction
The mandate of the European Commission to promote and support a programme of research and training in this field arises from Title II Chapter 1 of the Euratom Treaty. This Community programme also includes research on the harmful effects of ionising radiation. The aim of the Euratom Treaty is to promote the safe development of the peaceful use of nuclear energy. However, owing to the link with emission of ionising radiation and the exposure of workers and the public, this development cannot be sustainable without answering the legitimate questions of European citizens on the associated risks. In this regard, low and protracted exposures in the range of 0.1-1 Sv could be expected, but this range of exposures is even more likely to occur during the use of radiation for medical applications, in particular computed tomography. Low doses to normal tissues are also incurred during radiation therapy as a result of exposure to scattered radiation from the main field.

Strategic Research Agendas
The Euratom Framework Programme supported the work of the High Level and Expert Group (HLEG) in 2008 to set-up a Strategic Research Agenda (SRA) on low doses. This agenda promotes the sustainable integration of the research effort of organisations in European Member States, and the European Commission is contributing by providing Framework Programme financial support. This SRA will be the initial deliverable of the “Multidisciplinary European Low Dose Initiative” (MELODI) set up

by the HLEG. Composed so far of 9 European research organisations, MELODI is about to adopt a legal statute which will formalise its existence and allow its involvement in decision making on research strategies on low doses of radiation in Europe. Though it will be some time before the initiative becomes fully operational, this legal process is important to enable sustainability over the long term (20 years). Therefore, in the meantime, the European Commission supports research aimed at ensuring the Transition Research Agenda (TRA). The primary issues to be addressed by the TRA are the identification of priority proposals to be submitted following the Euratom Framework Programme calls in 2011 and 2012. In establishing the TRA, current and recent research findings will be evaluated in order to identify future priorities. This TRA is also, so far, being implemented through the 7th Euratom Framework Programme project DoReMi. More Euratom projects are expected to support the TRA in the future.

Challenge

The field of radiation protection and low dose in particular is a small world. Clear links are already established with other fields of research, especially the medical area. These links are beneficial for both Euratom and medical research. Indeed, through its long history of support to research in this field, which has led to a large number of excellent scientific publications, the Euratom programme contributes to advances in general understanding of the mechanisms of cancer induction and progression. This knowledge is now expanding to other health conditions such as cardiovascular disease. Similarly, the medical sector brings to the table its invaluable cohorts of exposed patients as part of imaging or radiotherapy protocols; these exposures are increasingly well recorded and contain reliable biological parameters. However, more efforts are needed to expand the synergy with other research fields. In particular, more and more knowledge is expected to be gained from the identification of gene expression, protein synthesis and their feedback on the gene expression, which are among the effects observed after exposure to ionising radiation. At low doses of radiation, the statistical power of epidemiology becomes less evident and needs to be substantiated by the observation of identified biochemical processes. Most of the other disciplines in the health sector are using similar approaches and similar tools. It is therefore time to carefully identify the synergies that can help Euratom to make the significant breakthroughs needed in the quantification of the risks arising from low doses of radiation and to open the radiation protection community to the wider scientific community.

In doing so, Euratom will attract new talents to radiation protection and this will also contribute to fulfilling the mandate from article 4 or the Euratom Treaty to develop training in this field. In this regard, Euratom research projects are not intended as a means to finance fellowships per se, rather they offer the possibility to engage graduate researchers in the research activities covered by a Euratom grant. The European Commission recommends that at least 5% of the overall budget of research projects is dedicated to such training activities.

Opening to the wider scientific community is also supported through large research projects such as DoReMi, which is a 6-year project with a total budget of €21M (of which €13M is from the Euratom programme). A significant part of this budget is foreseen for imbedded calls for proposals open to scientific teams which are

not yet part of the project consortium. Such a provision is expected to give flexibility to the research, which is likely to need competences that may not necessarily be available among the teams at the origin of the project, in order to address specific issues in the strategic agenda. This also demonstrates that large projects such as DoReMi, which are crucial in terms integration of research, visibility, optimisation of management resources and follow-up, are also making funding available to a wider community than is represented simply by the actual project consortium.

Conclusions

The SRA of MELODI and the TRA of DoReMi will provide crucial orientations for the Euratom programme of research and training on low doses of radiation. This approach is in line with the overall strategy of the Euratom Framework Programme in the area of fission and radiation protection, which is also becoming more closely aligned with the two other SRAs, one drawn up for research in nuclear safety and technology by the Sustainable Nuclear Energy Technology Platform (SNE-TP) and the other being established by the Implementing Geological Disposal Technology Platform (IGD-TP). With this strategy, the European Commission relies on the key nuclear research and industrial organisations in Europe to establish strategic priorities and ways of collaborating to implement agreed agendas. This in turn commits Member States' national research funding and thereby contributes to the joint programming with the Community in priority areas, such as energy research. The success of this strategy relies on the endorsement by the key players of a common vision for the future, their commitment to realising this vision through an agreed strategic research agenda, and the openness towards the wider scientific community and other socio-political stakeholders.

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New Build, environment and waste – application challenges for the 'new' RP

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