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MEMORANDUM

The state of radiological protection; views of the radiation protection profession: IRPA13, Glasgow, May 2012

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Abstract
The IRPA13 Congress took place from 14–18 May 2012 in Glasgow, Scotland, UK, and was attended by almost 1500 radiological protection professionals. The scientific programme of the Congress was designed to capture a snapshot of the

profession's views of the current state of knowledge, and of the challenges seen for the coming years. This paper provides a summary of these results of the Congress in twelve key scientific areas that served as the structural backbone of IRPA13.

1. Introduction

The thirteenth Congress of the International Radiological Protection Association (IRPA) took place in Glasgow, Scotland, from 14–18 May 2012. The Congress attracted 1468 radiological protection professionals from 68 countries, plus 234 exhibitor participants and 90 accompanying persons. The Congress drew 1413 abstract submissions, which were accepted as 320 oral presentations and 1093 poster presentations. A total of 24 refresher courses and two medical workshops, attracting 650 participants in all, were conducted. These statistics make IRPA13 the largest Congress in the Association's history, and most probably the largest-ever gathering of international radiological protection expertise.

The scientific programme content addressed 12 scientific areas which were divided into 66 distinct sessions of eight types:

- Plenary sessions: in these sessions the world's leading scientists and practitioners in their fields presented overviews of the current state of key topics in radiation protection.
- Key issue discussion sessions: these explored the current key issues in specific topics through expert discussion, helping us move towards the principal conclusions from the congress.
- Technical sessions and poster sessions: all the submitted papers and posters were presented within these sessions. Each of the 38 technical sessions aligned with a defined section of the area/topic map.
- Symposia: selected topics of current significance were addressed through specific sessions with invited speakers and wider discussions.
- Fora: key current aspects of the work of relevant international organisations were explored in these sessions.
- Refresher courses and workshops: each day began with a series of refresher courses which offered training and updating opportunities to delegates. A limited number of hands-on training workshops were also provided.

The IRPA13 scientific areas addressed the following topics:

(1) Biological and health effects of ionising radiation.
(2) Measurements and dosimetry.
(3) Radiation protection system development and implementation.
(4) Stakeholder engagement and involvement.
(5) Non-ionising radiation.
(6) Planned exposure situations: industry and research.
(7) Planned exposure situations: medicine.
(8) Planned exposure situations: radioactive waste management.
(9) Emergency exposure situations.
(10) Existing exposure situations.

(11) Protection of the environment.
(12) Fukushima Daiichi nuclear accident.

The IRPA13 Congress included several ‘firsts’. In order to facilitate IRPA actively becoming ‘the voice of the radiation profession’, the IRPA13 Congress was developed to capture the views of participating professionals with regard to what we know today, and with regard to what challenges we see for the future. To collect these views, the Congress included five key issue discussion sessions that were developed to allow participants to voice their views. For each of the 12 scientific areas of the Congress, this paper summarises the views collected by the area leads, session chairs and session rapporteurs. To supplement this approach, a draft of the paper was placed on the IRPA13 Congress webpage, and comments from participants have been incorporated so as to achieve, the best possible broad overview of the profession’s views on these 12 scientific areas. Table 1 presents an overview of the scientific areas and sessions of the IRPA13 Congress, giving for each area the ‘area lead’ responsible for the technical aspects of programme development, and listing of the types of sessions conducted in support of each area.

To further enhance IRPA as the voice of the radiological protection profession, digital access to information was a key preparation objective, resulting in the IRPA13 Congress being the most ‘digital’ IRPA Congress to date. All papers and posters were electronically submitted and were available digitally, and searchable, for all participants. In addition, use was made for the first time of digital media to reach the largest possible audience that wished to participate. This included webcasts, and the use of social media. The following are the ‘firsts’ in the use of digital media at IRPA13:

- The webcast of three sessions. These three webcasts allowed over 150 locations from around the world to view and participate in real-time in these sessions without having to travel to Glasgow. The three webcasts were: (1) the key issue discussion session on nuclear issues; (2) the plenary session and key issues session on the system of protection; and (3) the plenary session on the lessons and challenges following the Fukushima NPP accident.
- Using Twitter and Facebook to allow participants at IRPA13, and those on the three webcasts, to submit questions to the speakers for their response in live time during larger, selected session.
- Establishment of an IRPA13 Facebook ‘wall’, or homepage, that allowed those registered for IRPA13, the over 1500 radiation protection professionals worldwide, and others to engage each other on the topic of each session prior to, during and now after the Congress. The IRPA13 wall also allowed those present to post-pictures and comments about each session to quickly share and spread the information and knowledge gained from each session. A LinkedIn group was also set up prior to the Congress to allow for discussion of the issues.

The Congress theme, ‘Living with radiation, engaging with society’, was also a first in the sense that the profession’s interactions with ‘stakeholders’ in radiological protection situations were at the centre of discussions in many sessions. In making radiological protection decisions, be they for worker, patient, public or environmental protection, decision makers must address the science of radiological protection and its uncertainty, and the social values and economic situations of affected stakeholders and their diversity. The central theme of IRPA13 attempted to bring these complex issues to the forefront of discussions, to assist the profession to use ‘wisdom’, not just ‘science’, to implement radiation protection, to paraphrase what Rolf Sievert suggested in 1957 (*Am. J. Roent.* **77** (5) 914–9). Following this theme, the IRPA13 Congress engaged with society, with people affected by large-scale contamination events, and with students to give them a broad overview of what radiation protection is all about.

Table 1. Scientific areas and sessions of the IRPA13 Congress.

	Scientific area	Area lead	Number of accepted papers	Type and number of sessions: Plenary sessions	Key issue discussion sessions	Technical sessions	Symposia	Fora
1	Biological and health effects of ionising radiation	Richard Wakeford	130	1	1	3		
2	Radiological measurements and dosimetry	• Chris Perks • Hans Menzel	352			7	1	
3	RP system development and implementation	Caroline Schieber	138		1	4	1	2
4	Stakeholder engagement and involvement	Rick Jones	51	1	1	2	2	
5	Non-ionising radiation	Alastair McKinlay	36			1		
6	Planned exposure situations: industry and research		118		1	4		3
	• Nuclear fuel cycle	•Ralph Andersen						
	• Decommissioning and remediation	• Caroline Schieber						
	• NORM in mining and industry, and other non-nuclear industry and research	•Peter Shaw						
7	Planned exposure situations: medicine	•Claire-Louise Chapple • Keith Faulkner	191		1	5	1	2
8	Planned exposure situations: radioactive waste management	•Abrie Visagie • Gert Liebenberg	50			2	1	
9	Emergency exposure situations	Manuel Rodriguez	83			3	1	
10	Existing exposure situations	Astrid Liland	115			3	1	
11	Protection of the environment	Carl-Magnus Larsson	62			1	1	
12	Fukushima Daiichi nuclear accident	Ted Lazo	87	1		3		

The UK Society for Radiological Protection, which hosted the IRPA13 Congress, organised a very successful ‘schools day’, incorporating an exhibition and scientific presentation entitled ‘The importance of radiation in medicine’ given by Professor Peter Marsden, Head of the Medical Physics department of University College Hospital, London. About 1200 school children attended this event.

1.1. Summary of IRPA13 results

The International Congress Programme Committee developed the IRPA13 programme to collect and document a ‘snapshot’ of the radiological protection profession’s views of the current state of knowledge in May 2012, and of the foreseeable challenges remaining for the profession. The views of the IRPA13 Congress from these two standpoints are thus provided here for each of the 12 scientific areas addressed. Some of these areas are somewhat broader than others, and as such some sub-categorisation is provided.

2. Area 1. Biological and health effects of ionising radiation

This area has always been a key aspect of the IRPA Congresses, presenting the fundamentals of radiation biology and epidemiology on which health protection decisions are based.

2.1. The current state of knowledge

The excess risk of cancer predicted by current models to be produced by low doses (<100 mSv) or low dose-rates (<5 mSv h^{-1}) of ionising radiation is small—an effective dose of 100 mSv is predicted to produce, on average, a nominal lifetime excess risk of cancer of about 0.5%—so any effect of low-level exposure is difficult to detect against random and systematic variations in the background cancer risk (which is around 40% over a lifetime in developed countries). However, there is epidemiological evidence that supports the view that, for at least some types of cancer, a small risk does exist after exposure to ionising radiation at low doses or low dose-rates, and that this risk is compatible with the predictions of the models underlying the current framework of radiological protection set out in the ICRP 2007 Recommendations (models that are largely based upon the experience of the Japanese atomic-bomb survivors). The uncertainties surrounding the risk estimates obtained from these epidemiological studies of low-level exposure are substantial, but progress in gathering relevant evidence is likely to be made in the near future by large (and therefore statistically more powerful) studies of medical exposures (in particular, CT scans), natural background radiation and nuclear industry workforces, among others.

Outstanding challenges to the current system of radiological protection include the dose and dose-rate effectiveness factor (DDREF, the reduction factor applied to risk estimates obtained from studies of moderate-to-high doses received at a high dose-rate when low dose or low dose-rate exposures are involved, which for cancers other than leukaemia, is assumed by the ICRP 2007 Recommendations to be 2), and the risk of non-cancer somatic diseases (especially blood circulatory system diseases) at low doses or low dose-rates. Epidemiological evidence currently suggests a DDREF less than 2 (possibly not much more than unity), while experimental evidence indicates a DDREF of 2 or more—the satisfactory resolution of this issue will not be straightforward. The combined evidence from epidemiological studies supports a statistical association between low doses/dose-rates and the risk of circulatory disease, although the interpretation of the findings of such studies is complicated by the influence of other major risk factors for these diseases in the groups studied. Moreover, whereas it is accepted that tissue damage from high doses/dose-rates increases the risk of circulatory disease, no biological mechanism for any effect of low-level exposure upon cardiovascular and cerebrovascular diseases is yet established, which is a major obstacle to any potential causal explanation for the epidemiological association.

Recently, the dose limit for the lens of the eye has been substantially lowered by the ICRP because of the accumulation of epidemiological evidence for an increased risk of cataracts at low doses/dose-rates. Both the dose limit for workers and that for members of the public have been the subject of controversy—in particular, the basis of the evidence for the recommended annual occupational dose limit for the lens of the eye of 20 mSv has been questioned, primarily because of the potential implications for medical workers performing interventional procedures.

Individual radiosensitivity is a topic that has been much discussed over the years, and the discussions continue. It is known that certain factors, such as age at exposure and sex, affect the radiation-induced excess risk of cancer, as do co-exposures, such as tobacco smoke, and there are rare heritable genetic conditions that substantially increase this risk. However, how much risk varies from person to person in the general population is a matter that remains to be resolved, and has potentially important implications for radiological protection. For example, one suggestion is that radiation-induced cancers appear in a relatively small susceptible sub-group, and that the remainder of the population is (more or less) risk free, so that under these circumstances the sub-group would be the object of protection. A better understanding of radiobiological mechanisms is likely to be the only way that this issue will be satisfactorily resolved.

The risks associated with non-ionising radiations continue to attract media attention and scientific debate. These issues are discussed under 'Area 5. Non-ionising radiation'.

The accident at the Fukushima Daiichi nuclear power station in Japan in March 2011 has once again focused attention on the risk to health posed by low-level exposure to radiation, particularly the future risk of cancer. Some groups claim that the risk from such exposure has been grossly underestimated while other groups claim that the risk models presently underlying radiological protection exaggerate the risk, and that there may not actually be any excess risk following low-level exposure. A current topic of debate is whether the biological response to low doses or low dose-rates of radiation may be different from that following moderate-to-high doses received at high dose-rates (exposure conditions that are the primary epidemiological source of present risk estimates), which, it is argued, overwhelm defence mechanisms, whereas this does not happen at low levels of exposure. Unfortunately, the complexity of radiobiology (and indeed, biology) is such that it is not possible to arrive at any mechanistic conclusion that can be described as firm—an example of this is the fundamental debate that is taking place as to whether the principal mode of action of radiation in terms of its carcinogenetic effect is at the genetic (i.e. within the cellular DNA) or epigenetic (i.e. consequent tissue effects outside the DNA) level. Information on radiobiological mechanisms is accumulating rapidly as new investigative techniques are applied in the laboratory, but although a 'break through' in understanding is sometimes claimed, it seems that a proper appreciation of the mechanisms involved in radiation-induced cancer is still someway off.

The present 'linear no-threshold' (LNT) risk models that form the foundation of current radiological protection at low doses or low dose-rates of exposure to radiation are empirically based upon epidemiological results at moderate-to-high doses delivered at high dose-rates, and have been the subject of some criticism. Nonetheless, there is epidemiological evidence of some small risk after low-level exposure, and this evidence seems to have been supported by recent studies. However, it is unlikely that epidemiological evidence alone will provide a satisfactory solution to the question of the level of risk posed by low-level radiation exposure—the risks are so small compared to background risks that any putative radiation-induced excess risk could be due to variations in these other factors—so reliable biologically based modelling will also be required. How long we may have to wait before a generally accepted mechanistic basis of radiation-induced cancer is available is another matter.

2.2. Challenges for the coming years

Many scientific challenges to better understanding of radiological risks remain. For example, there is a need to more completely understand the nature of risks to high and low doses and dose-rates, and any differences that exist in biological mechanisms for high and low doses and dose-rates that may induce cancer or contribute to cancer induction. The practical implications of such understanding, for things such as the value of the DDREF and the use of the LNT assumption as a basis for the optimisation of protection, could be far reaching. The search for more detailed understanding of individual risk variations, of risks from non-ionising radiation, and of non-cancer risks remains challenging, with much research now focusing on the nature of cancer risks as genetic, epigenetic, or both. The complexity of biological science will most likely continue to present opportunities for further research well into the future.

3. Area 2. Measurements and dosimetry

As with previous IRPA Congresses, this area represents the largest number of submitted abstracts, with 25% of all contributions to the Congress in the measurement and dosimetry section. This demonstrates a thriving field in which continuing development and improvement to existing methodologies and systems (external, internal, retrospective and numerical) is actively being pursued.

3.1. The current state of knowledge

Dosimetry and measurement of radiation is dynamic and not static, requirements change based on political and sociological catalysts that are not always based on scientific need.

As regards external dosimetry, photon dosimetry is well established, while neutron and mixed field dosimetry remains a challenge. For example, many methods exist for the characterisation of external doses arising from naturally occurring radioactive materials (NORM), but variabilities arise due to soil/bedrock composition. Dose conversion coefficients for external radiation of workers based on ICRP Publication 103 have recently been published (ICRP Publication 116).

For monitoring of occupational exposure in radiology, the ICRP-recommended two-dosemeter method is widely adopted for certain medical workers e.g. radiologists and cardiologists. However, the correlation between head/trunk and extremities/trunk needs to be further established. Dose to the lens of the eye (see below) is of particular concern in this field. Patient dose is also of concern, and increasing focus is given to the assessment of dose due to CT procedures.

In post-accident dosimetry, usually dosemeter data are not available. Various methods of retrospective dosimetry remain in development (including electron paramagnetic resonance, EPR), optically stimulated luminescence (OSL) using available materials including individual samples (fingernail clippings, teeth, dental implants etc) and personal items (consumer electronics, mobile phones etc).

In biological dosimetry, established techniques include dicentric chromosome analysis and cytokinesis block micronucleus assay. Inter-laboratory comparisons are undertaken.

There are also a number of newer techniques, including: premature chromosome condensation, gene expression and fluorescent in-situ hybridisation (FISH). FISH tends to over-estimate (compared with dicentric assay) for assessments shortly after exposure but has the ability to provide a long-term 'dose record'. The new methods have potentially higher throughput and faster results, but further testing and benchmarking is necessary.

For radiation monitoring after a large-scale radiological event, triage and treatment, sample handling, availability of results (with sufficient accuracy and precision), non-uniform irradiation, and transport of critical samples are key issues.

The revision of the dose limit to the lens of the eye from 150 mSv to 20 mSv yr^{-1} recommended by ICRP was discussed in various topic sessions. Currently, dose to the lens of the eye is often not measured or reported, and calculation based on Hp(10) and Hp(.07) is not always viable, requiring a specific dosimeter that can accurately detect and measure dose at Hp(3). Actual measurements demonstrate that there will be instances where doses will exceeded the 20 mSv yr^{-1} limit. Additional protection measures such as leaded glasses and additional shielding may be needed. There is clearly a need for the development of dosemeters and methods for the measurement of eye doses. Manufacturers and dosimetry services are developing dosemeters and systems to do this, and employers are undertaking studies to understand the extent to which dosimetry will be required, and how this might be done with as much compliance as possible, but without overly inconveniencing those required to perform delicate work. There is a need for convergence on instrumentation and for harmonisation of procedures, emerging from a consensus in understanding the scope and characteristics of the issue in real circumstances.

Other issues raised at the congress in relation to dosimetry included:

- The increasing use of web-based reporting systems and for dosimetry that does not require returning a dose of record dosimeter, such as TLD, OSL or film, security of data and ease of use is essential.
- Accreditation of the entire system is required to provide confidence in the dose reported to the individual, and, there must exist a QA system that validates the web-based dose.
- Neutron dose measurements must be able to minimise the effect of gamma dose to the specific type of dosimeter used.
- Dosimetry systems must analyse negative measurements as well as positive measurements, counting statistics, etc. One should never automatically eliminate negative results, and shall use all data when investigating exposure.

In numerical dosimetry, computational adult reference phantoms based on medical images are being used increasingly. These are now developed for both genders, adult, child and baby, of variable size, weight and increasing reality and the need for increasing accuracy of dose assessment. The optimisation of computational dosimetry is essential for their application in treatment planning software (TPS) systems, assessment of dose to members of the public (especially those potentially exposed in unplanned events and for epidemiology studies) and internal dosimetry. Computational dosimetry is also highly developed as a tool for the development of instrumentation, and for the design of shielding (both in the nuclear industry, for example in waste drums and internal storage, and in the medical field e.g. the design of PET facilities)

3.2. Challenges for the coming years

It is certain that, in this highly active field, there will be continuing political, economic, social and technological pressures to improve methods for assessing doses both by measurement and by computations and bydosimetry systems.

Of particular concern are:

- Further international harmonisation of procedures and standards of dosimetry is required for:
  - patient protection, and
  - operational radiation protection for occupational exposures.
- A greater knowledge of uncertainties in dose assessment of all types.
- The system of dosimetric quantities used in radiation protection is complex and should be reviewed with regard to communication with the public. This was echoed in the sessions on the lessons learned from the Fukushima Daiichi nuclear accident and in sessions on communicating with the public.
- The requirements for increasing web applications necessitate the careful adoption of increasing security measures in handling personal information.

4. Area 3. Radiation protection system development and implementation

Another key area of IRPA Congresses discusses the evolutionary aspects of the system of radiological protection. The current ICRP system of radiological protection, as described in Publication 103, was approved in 2007 and as such this is the first opportunity that the profession has had to discuss its details and direction.

4.1. The current state of knowledge

4.1.1. Evolution and implementation of the RP system/regulation. The RP system is based on the recommendations from ICRP. It is now a current ICRP practice to involve relevant stakeholders in the process of elaboration of the recommendations, and in the finalisation of publications, which are posted for comments before their completion. Some international organisations (e.g. the CRPPH of OECD/NEA), and dedicated professional networks (e.g. NERIS) take this opportunity to gather specific input and comments from their constituencies, thus developing more broadly consensus views for consideration by the ICRP.

The new general recommendations of the ICRP (ICRP Publication 103) have now been introduced into the new International Basic Safety Standards (BSS) co-sponsored by six UN organisations (IAEA, ILO, WHO, FAO, PAHO, UNEP) and two intergovernmental organisations (OECD/NEA and EC) as well as into the new European BSS from the European Commission, recently revised in both cases. Some countries have already begun to change their regulations according to these new recommendations. Again, it can be noted that there is an increasing willingness to involve interested parties in the elaboration of international standards and regulations.

Finally a noticeable search for harmonisation of regulatory requirements between countries can be seen. The main example being the creation of HERCA, which brings together the Heads of 47 European Radiological Protection Competent Authorities from 29 countries. Among the objectives of HERCA are the willingness to discuss and where appropriate, express its consensus opinion on significant regulatory issues, as well as the development of a common approach to radiological protection issues. Similar experiences are being developed in other regions of the world, such as the Foro of Iberoamerican Radiological and Nuclear Regulatory Authorities (FORO).

4.1.2. Education and training. One can see a huge development of radiation protection training schemes for RP professionals and other workers concerned by radiation protection. These include training reference standards for radiation protection experts and officers (as defined by the European Directive), MSc or PhD level courses in radiation protection, and training in the radiation protection from naturally occurring radioactive materials.

Accreditation systems for RP professionals in various fields (instrumentation, medical, nuclear, ...) are now developed in many countries.

Many initiatives are also undertaken in many countries regarding teaching radiation protection at school (primary and secondary schools). This can prove to be very important for attracting young people to study radiation protection, and for attracting young professionals into radiation protection carriers.

4.1.3. RP culture. Elements contributing to the development of RP culture are now well identified. Several actions have been undertaken by regulatory bodies, professional associations, networks, etc to disseminate this culture in various fields (industry, medical, public, ...). Among the international actions of particular interest, the IRPA guidelines for enhancing radiation protection culture among RP professionals stands out. The needs expressed by the IRPA Associate Societies during IRPA13 discussions point to the visibility to IRPA's initiative for the promotion of RP culture principles, for instance the importance of developing common assessment tools, of highlighting RP ethics, and of the role played by IRPA's Associate Societies with RP professionals both in the medical and industrial field. RP culture could be considered as feed culture.

Also worthy of interest for the RP community is the practical guidebook on optimisation of radiation protection (ALARA) from the European ALARA Network.

4.2. Challenges for the coming years

4.2.1. Evolution and implementation of the RP system/regulation. While the ICRP system of radiological protection is increasingly stressing the importance of stakeholder involvement in the decision aiding and decision making processes, it is clear that, in some specific exposure situations (medical, public, NORM, etc), progress is still needed in order to better involve relevant stakeholders in radiation protection programmes or actions, and to facilitate their implementation.

Another important issue is that of the development of effective national regulatory infrastructure for the control of sources and for radiation protection in all countries. The IAEA has developed various support programmes and services that are made available to its member States, to assist them if necessary in the establishment and strengthening of these infrastructures.

4.2.2. Education and training. Although there has been an expansion of RP programmes for the education and training of RP professionals and other workers concerned by radiation protection, such programmes are still missing in some countries and should be developed.

While efforts are made in Europe for the harmonisation and the reinforcement of the training of radiation protection experts (RPE), it would be appropriate to think also about the lower levels of qualifications, as there are large groups of both radiological workers and RP technicians who are already quite mobile and work in several countries.

It is necessary to prepare the next generation of radiation protection workers early enough. The school project performed during the Congress was a good example of what can be done to attract young professionals.

Finally, advantage should be taken of the development of new technologies such as e-learning to foster the development of training schemes in places where dedicated schools are not available.

4.2.3. RP culture. Further development and dissemination of the RP culture is still necessary among professionals and the public due to an increase of risk awareness, the constant development of scientific knowledge, a decreasing number of RP professionals, and the introduction of new exposure situations.

4.2.4. Fukushima-related issues. It should be noted that the March 2011 accident at Fukushima Daiichi nuclear power plant has resulted in many issues for and challenges to the system of radiological protection. These were addressed during the Congress and are discussed later in this paper under Area 12 (section 13).

5. Area 4. Stakeholder engagement and involvement

This area is central to the theme of IRPA13, and represents one of the key challenges facing the radiological protection profession, as illustrated graphically in the national and international response to the Fukushima NPP accident.

5.1. The current state of knowledge

The inclusion of a plenary session, a key issue discussion session, two technical sessions, two symposia and three refresher courses on *Engaging with Society*, scientific area 4, showed that stakeholder engagement and involvement has become more and more important to the success of the radiation protection profession.

The sessions demonstrated that stakeholder engagement can be a valuable decision making or aiding tool for the radiation protection profession in order to achieve implementable and sustainable decisions. However, the radiation protection professional and their organisations/employers need new skills in order to implement effective stakeholder engagement. The Congress clearly identified that stakeholder engagement and the associated risk communication is a science and participants need to prepare accordingly.

In the symposium on *Affected People's Experiences* it became clear that people affected by radiation exposures, including patients and populations living in contaminated areas, benefit greatly when the radiation protection profession implements stakeholder engagement to identify and address their issues. Those attending the session heard first-hand accounts from residents living in contaminated areas (e.g. the Sami people of Norway and representatives from Belarus) how their lives have changed and how the radiation protection profession has helped them and can further help them to enhance their quality of life.

The symposium on *Teaching Radiation Protection to Students* shared the experiences of many countries highlighting their initiatives to teach students and teachers, from kindergarten to the last year of pre-university schooling, about radiation in order to help them make informed decisions about radiation and radiation exposure. Participants at the session gained valuable knowledge, information, and contacts to allow them to return home and enhance existing or begin similar activities.

The use of the latest communication technologies (e.g. social media, webcasts) enhances participation and transfer of knowledge and information within the profession and with stakeholders. Use of more web-based communications technologies allows the profession to more quickly reach out to stakeholders to keep them informed of activities, post-monitoring information, and to also engage young professionals more effectively.

The Congress also identified that the IRPA *Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement* (www.sfrp.asso.fr/IMG/dpf/Guidling_Principles_IRPA.pdf) are sound guidance to promote stakeholder participation. Use of the guiding principles provides a valuable resource to professionals to help them to more effectively establish productive relationships with stakeholders.

5.2. Challenges for the coming years

The nine activities and sessions conducted in support of the scientific area *Engaging with Society* identified a number of challenges facing the radiation protection profession, the professional and their employers or organisations.

Of particular note is the importance of collecting and sharing lessons learned and best practices in the conduct of stakeholder engagement that upholds the dignity of stakeholders. Much work with stakeholders is being conducted worldwide, particularly post-Fukushima NPP accident. It is critically important that the profession document and share lessons learned in the conduct of these stakeholder engagement activities. It would be helpful if an international organisation could be identified to provide this much needed service to the profession and hence enhance its effectiveness.

As the presentations showed, stakeholder engagement and the associated risk communication is clearly a science, and the radiation protection profession should respond accordingly. This means that those to be involved in risk communication need to be educated, trained and given experience prior to being assigned or put in a position to conduct stakeholder engagement. This is necessary to protect the integrity of, and stakeholder trust for, the professional, profession and organisation they represent.

There is also a need to include and emphasise the need for stakeholder engagement during emergency planning, particularly for post-emergency activities during recovery and remediation. Establishing a relationship with stakeholders prior to an emergency will allow their concerns to be identified, and provide an opportunity to build a relationship of trust that will be essential in the event of an emergency. These stakeholders are also often a resource to provide leadership in their communities.

It is desirable that the radiation protection profession and IRPA Associate Societies build on the experience of initiatives to teach radiation basics to students and teachers, which were demonstrated at IRPA13, to expand these initiatives to a broader spectrum of society. This would be part of the profession taking the opportunity to teach as broad a spectrum of society as possible in order for stakeholders to make informed decisions about radiation.

The radiation protection profession would benefit by taking definitive actions to expand the use of the latest communications technologies to enhance the efficiency and effectiveness of the profession. Reaching out to stakeholders and young radiation protection professionals using the latest internet-based communications tools can only help the profession to more effectively serve society.

Radiation protection professionals and IRPA Associate Societies would benefit from expanding the implementation and use of the IRPA *Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement*. The Associate Societies could support this expansion by providing incentives for professionals to embrace and use the IRPA guiding principles.

6. Area 5. Non-ionising radiation

Non-ionising radiation covers a very large spectrum of wavelengths that tend to be covered, with respect to protection aspects, in the categories of electromagnetic fields (of high frequency or large static power), electromagnetic radiation in the optical range and ultrasound radiation.

6.1. The current state of knowledge

6.1.1. Electromagnetic fields. In the last few years, the International Commission on Non-Ionising Radiation Protection (ICNIRP) has been revising the full set of its guidelines for safe exposure of workers and the general public to electromagnetic fields, over the whole frequency spectrum from static fields (0 Hz) to the upper limit of microwaves (300 GHz). Such revision is based on comprehensive reviews of the literature carried out by ICNIRP itself, IARC and WHO's International EMF Project. The resulting up-to-date overview of knowledge can be summarised as follows, for each of the frequency regions in which the non-optical EMF spectrum is traditionally divided.

6.1.2. Static magnetic fields. The investigation range is limited by the technical and economic difficulties of creating very high fields over large volumes, comparable to the size of human bodies. The upper limit is essentially given by fields generated in MRI scanners, which provide the largest body of information on biological and health effects. No acute adverse effect is observed up to the maximum field strengths presently attained, of the order of 8 T. This is consistent with theoretical models suggesting a number of plausible health effects, but only above thresholds much higher than such a value.

6.1.3. Low-frequency electric and magnetic fields (up to 100 kHz). Recent studies, while confirming the stimulation of electrically excitable tissues as the basic interaction mechanism for acute health effects, have better clarified the frequency dependence of the associated thresholds. The most relevant advances have been achieved in the area of dosimetry. Detailed numerical models of the human body, with linear resolution lower than 1 mm, allow precise characterisation of the internally induced electric field. This quantity has replaced the induced electric current as the biologically effective quantity, in terms of which basic restrictions are expressed. Biological studies *in vitro* and *in vivo* keep showing no consistent effect below the recommended exposure limits. As regards possible long-term effects, further epidemiological studies are not recommended in research agendas (e.g. by WHO), since they are not expected to change the overall pattern of evidence. Indeed, recent reviews including the latest studied confirm IARC's evaluation of extremely low-frequency (ELF) magnetic fields as possibly carcinogenic.

6.1.4. Radiofrequency electromagnetic fields (100 kHz–300 GHz). Similarly to low-frequency fields, recent research has provided further support to the conclusion that thermal effects are the only established adverse acute effects of exposure to radiofrequency (RF) fields. A number of biological effects below the recommended exposure limits have been suggested theoretically or experimentally, but either the studies have not been replicated, or the health implications of biological findings is unclear. The most relevant advances come from dosimetry and epidemiology. The development of 'virtual families', i.e. numerical phantoms of different sizes and shapes allow a refined characterisation of electromagnetic energy distribution inside the body. While a number of non-thermal effects have been suggested by sparse studies, most findings have not been replicated, and the overall evidence is negative. Regarding epidemiology, large-scale studies, both cohort and case-control (the Interphone project) did not provide evidence of a material increase of brain tumours in mobile phone users. However, the existence of divergent results from a few other studies led IARC to classify radiofrequency electromagnetic fields as possibly carcinogenic (Group 2B).

6.2. Challenges for the coming years

Knowledge of the risks from electromagnetic fields is fairly well established, however some challenges, as mentioned, remain. In terms of electromagnetic fields, while no special new research is recommended, monitoring and recording of exposure conditions and health status of workers would be of use, e.g. to evaluate the feasibility of epidemiological studies. In terms of *low*-frequency electric and magnetic fields, while no further epidemiological surveys are recommended, a research priority is the identification of alternative explanations for the observed association between magnetic fields and childhood leukaemia. Finally, with regard to radiofrequency electromagnetic fields, research priorities include mainly studies on newborn and children, and especially studies in relation to the use of mobile phones by young people.

6.3. The current state of knowledge

6.3.1. Optical radiation and ultrasound. Life on Earth has evolved under diurnal exposure to optical radiation from the Sun. Human eye and skin exposure from this natural source presents benefits to health, as well as risks. Therefore, unlike most other radiations, optimisation is a balance between adequate exposure to receive the benefit and limitation to avoid unacceptable risk. This balance is complicated by the increasing number of artificial sources of optical radiation.

Ultraviolet radiation (UVR) is a known carcinogen (IARC Group 1). However, whilst the link between non-melanoma skin cancers and cumulative exposure to UVR is fairly well established, the mechanism for malignant melanoma (MM) induction is unclear. Short duration high levels of exposure, for example from a sun-bed or a holiday in the sun, may increase the risk. Solar UVR exposure is also the primary source for vitamin D production in humans. There is clear evidence that vitamin D is essential for good bone health. However, the benefits may be wider.

Visible optical radiation (light) has the obvious benefit of allowing us to see. However, it is also important for entrainment of the circadian rhythm. The action spectrum for this circadian entrainment is still being developed and needs more research. However, the indications are that the peak of the action spectrum is from 460 to 480 nm, which is close to the peak of the blue light (photochemical) hazard function (460 nm). It is essential therefore that the benefits and risks are balanced.

Infrared radiation provides warmth. However, it can also cause burns at high irradiance levels. Further research is required to determine the threshold for adverse health effects in the eye. Although the exposure limits for laser radiation at wavelengths above 3 μm are assumed to be a constant irradiance (for exposures longer than 10 s) and independent of wavelength, there is uncertainty over the values for non-laser sources and especially sources in the terahertz region forming the boundary between optical radiation and microwaves.

The laser exposure limit values make assumptions about the minimum size of retinal images formed from collimated beams. In the future, consideration needs to be given of techniques that use adaptive optics to focus beams to spots smaller than the theoretical diffraction limit.

One of the challenges for optical radiation is assessing personal exposures for epidemiological studies. Due to the critical organs being the skin and the eyes, it is important to develop a link between ambient exposure levels and actual personal exposures. People rarely stare at sources and much of the skin is usually covered by clothing.

Laser and non-laser optical radiations are used in an increasing number of medical diagnostic applications. The exposure limit values published by ICNIRP are intended for the eyes and the skin. A number of diagnostic applications expose internal tissues to optical radiation, either via natural orifices, or through incisions. Exposure limit values do not exist for such exposures.

Medical ultrasound has been in use for over 50 years. The limits on personal exposure have been maintained due to the physical limitations of the equipment. However, new high intensity ultrasound sources are being developed and used.

6.4. Challenges for the coming years

In terms of risks from solar UVR, further research is needed to ensure that advice on safe exposure to solar UVR is evidence-based. In the infrared range, uncertainty over the values for non-laser sources, and especially sources in the terahertz region forming the boundary between optical radiation and microwaves, may pose challenges to scientifically-based regulatory approaches. In the area of laser exposures, for protection reasons consideration needs to be given of techniques that use adaptive optics to focus beams to spots smaller than the theoretical diffraction limit. Guidance also needs to be developed to ensure that patients undergoing treatments using lasers are not at risk of adverse health effects, or to permit treatment-required higher levels of exposure than would be permitted from the skin exposure limit value. In terms of medical ultrasound exposure, the advent of high intensity ultrasound sources raises new challenges in terms of limits and dosimetry.

7. Area 6. Planned exposure situations: industry and research

Technical area 6 was designed to cover, separately but in a consistent fashion, many aspects of radiological protection in planned exposure situations in industry and research. Presentations were divided into those addressing the nuclear fuel cycle; the non-nuclear industry; research, transport and security; decommissioning activities; and NORM in mining and industry. The current status and future challenges in each of these four areas are thus presented separately.

7.1. The current state of knowledge

7.1.1. Nuclear fuel cycle. The technical session and posters covered a broad range of topics, including the following:

- nuclear power—routine operations and new build;
- uranium mining;
- fuel fabrication;
- production of radioisotopes and radiopharmaceuticals.

The radiation protection framework across these areas is well established and has proven effective in controlling and optimising radiation exposures to workers and the public and radiological releases into the environment. Sharing experience and lessons learned with regard to facility and process design, operation and regulation remains the key factor for continuing to improve performance and minimising the potential for accidents. Periodic updating of the scientific and technical bases for regulations and standards helps provide more realistic assessments of sources and exposures and improves credibility and transparency in communicating about radiation and radiation safety.

The advent of new build creates the opportunity to reconsider and redefine radiation protection issues as regulations and standards are significantly updated and revised to address new reactor designs, siting and operations. In addition to the 435 reactors that are currently in operation, 63 new reactors are under construction and more than 150 are on order or planned. The majority of new reactors under construction or planned are in non-OECD countries which brings forward a more comprehensive consideration of national infrastructure, economic and political issues that include fundamental evaluations of radiological protection aspects (e.g., justification, limitation and optimisation).

7.1.2. Non-nuclear industry, research, transport and security. The technical sessions and posters in this area covered a total of five IRPA13 sub-topics: management and security of sources; accelerators and fusion; non-nuclear industry and research; security screening; and transport of radioactive materials. The overall impression from this wide range of planned exposure situations is that the radiation protection framework is well established and is effectively implemented in most cases. The use of dose constraints in planning and optimisation is also increasing, especially in respect of new applications and installations. Other positive developments are the introduction of security regimes for radioactive sources, the development of ALARA benchmarking and self-assessment tools, and the use of networking to share examples of good practice and disseminate lessons learned.

The transport of radioactive materials also subject to well established regulatory requirements, and is undertaken with due consideration to the twin requirements of safety and security. Having said that, there is less evidence of optimisation in practice, and there remain issues with denial of shipments.

Also in this area the World Institute for Nuclear Security (WINS) organised a forum on the role of the radiation protection professionals in the security of radioactive sources. Participants strongly agreed that radiation protection professionals had a meaningful role to play in assuring that adequate security measures for radioactive sources were implemented. However, they felt that additional knowledge and training might be needed to fully carry out that role. It appeared that the resources to assist radiation protection professionals in obtaining the needed competency and knowledge is steadily becoming more available and that the strains between the security and safety communities is decreasing. The participants felt that security should almost certainly be an ongoing aspect of IRPA's activities and a part of future IRPA regional and international conferences.

7.1.3. Decommissioning. Decommissioning is the final phase of the life cycle of any nuclear facility. Today more than 450 facilities (nuclear power plants, research reactors) are finally shut down or under decommissioning or for which decommissioning has been already completed, all resulting in different technical and radiological end-states.

Radiation protection of workers and the public—together with the management of radioactive waste and of spent fuel (if there is any at the facility in question)—is the central challenge during decommissioning projects. Depending on many influencing parameters (e.g. radiological inventory, complexity of the nuclear facility, decommissioning strategy or approach to structure the project), radiation protection measures are different and specific for each individual decommissioning project. It is therefore most important to get radiation protection professionals involved as early as possible in the decommissioning planning.

As with the operation of facilities, it is essential that all levels of employees, from executive level to craft workers, understand their responsibilities and commitment to the ALARA program.

7.1.4. NORM. NORM is omnipresent, and the key to protection is knowing where controls are required, and (importantly) where they are not. Much progress has been made in the last few years in identifying the NORM industries and processes that may require (some form of) radiological protection control. At the same time, there has been progress towards internationally accepted exemption criteria (in terms of mSv y^{-1} and Bq g^{-1}), below which controls are not necessary. Having said that, there is still a debate about whether a single set of exemption criteria is appropriate for all exposure scenarios.

The ICRP exposure situations—specifically planned and existing—are often a source of confusion in relation to NORM, as was evident between the two corresponding technical sessions at IRPA13, and it is still not clear how helpful such a distinction is in practice.

There is a tendency to use models to estimate doses (both for workers and the public). Models have tended to be more conservative than realistic. Encouragingly, a number of the IRPA13 papers did include a sensitivity analysis of the parameters used in dose modelling.

Where regulatory controls are deemed necessary, there is broad agreement that a graded approach should be adopted, and some details of how this might be implemented in practice are starting to emerge.

7.2. Challenges for the coming years

7.2.1. Nuclear fuel cycle. A key issue discussion session focused on emerging challenges and opportunities in radiation protection for the nuclear industry and included summaries of relevant sessions form the 2010 IRPA mid-term conferences in Helsinki and Tokyo, as well as a cross section of regulatory and industry perspectives from the International Atomic Energy Agency (IAEA), Nuclear Energy Agency Committee on Radiation Protection and Public Health (CRPPH), World Association of Nuclear Operators (WANO), International System of Occupational Exposure (ISOE), Japan and China.

An ongoing operational challenge is to sustain continuous improvement in controlling and minimising occupational radiation dose. The decades-long emphasis on collective occupational dose as a key indicator of radiation protection performance has yielded significant (order of magnitude) reductions in dose across the nuclear industry. For the first and second-quartile facilities, further incremental dose reduction relies on longer term investments such work process changes, source term management, new shielding technologies, and real-time personnel monitoring and communication stations. Near-term opportunities lie in transferring knowledge and experience to bring third and fourth-quartile facilities up to first and second-quartile standards and in increasing the focus on individual dose reduction for higher dose workers and tasks.

Achieving improvements in controlling and minimising public radiation dose poses challenges that are different for those for occupational dose. Individual public doses from routine operations are generally at or below μSv ranges with correspondingly small collective doses. Further dose reductions are difficult to rationalise in the context of optimisation (i.e., costs versus benefits) and fall largely within the uncertainties in the measurements and models used to estimate public dose. Opportunities for improvement include increasing the focus on such things as preventing inadvertent or unplanned releases (e.g., from spills or leaks), further reduction or elimination of radioactive liquid discharges, and improved water management practices and fuel integrity performance.

New build represents a large opportunity to integrate the vast, global base of operational knowledge and experience into new plant design and operating procedures—especially considering a life-cycle approach from initial construction and start-up through ultimate decommissioning. Additional challenges, however, are posed by the ageing of existing facilities and extension of operating licenses with commensurate replacement and refurbishment activities and the implementation of post-Fukushima safety enhancements.

Several challenges are emerging in regard to human resources. The ‘ageing workforce’ is a global situation with an accelerating rate of retirements and attrition posing challenges in knowledge transfer and development of a new workforce of skilled and experienced personnel. Specialised refuelling and maintenance activities are becoming a highly competitive and global business with increasingly mobile groups of highly skilled (and often higher dose) workers leading to trans-boundary issues such as differing dose standards, dose record systems and radiation protection standards. The emergent global nature of the nuclear industry also entails the need for a shared global radiation safety culture that fosters open, timely and critical exchange of experience and lessons learned and a commitment to continuous improvement.

Changes in societal expectations are leading to increased challenges in communication and stakeholder engagement. The demand for credible, accurate and complete information is becoming real-time as a reflection of global access to the internet and social media. Effectiveness in risk communication has become a requisite part of the radiation protection profession's skill set. A continuing challenge is to better integrate radiation risk management and communication within a broader context of general risk management and communication.

All of these challenges are compounded by the increasing trends in new build and decommissioning on top of the continued and extended operation of existing facilities.

7.2.2. Non-nuclear industry, research, transport and security. The focus on the security of radioactive sources is expected to continue. In particular, there are challenges with implementing security requirements in small/medium enterprises and in specific sectors such as higher education.

Concerns have continued to be expressed about industrial radiography, in which there are questions about the doses received by workers, the frequency of radiation accidents, and the radiation safety culture in general. These are long-standing issues, and it is clear that a renewed focus, and even a new approach, is required to address these challenges.

7.2.3. Decommissioning. While for many technical questions standard market solutions are available or can be developed for a given situation, decommissioning project challenges may arise from radiological characterisation work (which may have to be performed at several phases of the project), and from radiological surveys necessary after the completion of decommissioning to demonstrate that the intended final end state has been reached and complies with regulatory requirements. It should be noted that some countries have not established clearance levels for materials or site release criteria.

Decommissioning activities are quite often undertaken by workers who are not familiar with the nuclear or radioactive environment. Training and education of these workers in all aspects of radiation protection is thus of particular importance and remains a challenge.

International experience exchange on decommissioning lessons learned need to be fostered, for example by using the Information System on Occupational Exposure (ISOE) developed by OECD/NEA and IAEA. Better links between the persons in charge of dismantling and those of designing new plants would help to integrate decommissioning experience into the design of new facilities, and facilitate future decommissioning.

7.2.4. NORM. As indicated above, clarification of planned versus existing exposures (and consequently the application of dose limits and dose constraints, or of reference levels) is very much needed. NORM is international, and the challenge is to achieve a proportionate, harmonised and coherent regulatory approach, which industries can understand and implement.

The introduction of regulatory controls brings further challenges, such as the derivation, selection and use of NORM-specific parameters to assess individual doses, and ensuring that there is sufficient radiological protection expertise within NORM industries to apply these within a radiation protection programme. Availability of expertise and resources for radiological protection is a particular challenge in the oil and gas industries in developing countries, where the emphasis is on production.

There are many other challenges—such as the expansion of uranium mining, the assessment and control of radon exposures, and dealing with legacy sites. However, the most significant challenge overall is likely to remain the management of NORM residues, for which more options (including, recycling and re-use, as well as final disposal) are still required.

8. Area 7. Planned exposure situations: medicine

Area 7 was devoted to the medical sector, and provided a full programme comprising five technical sessions, two fora, a symposium and a key issue discussion session. In addition there was a teaching programme running throughout the week that consisted of a series of five refresher courses and two practical workshops—the latter a first for IRPA. There were a total of 23 invited speakers, 26 proffered oral presentations and a total of 170 submitted posters.

8.1. The current state of knowledge

8.1.1. Radiotherapy. The basic principles of proton therapy and its potential advantages over conventional therapy were outlined, and the radiation protection requirements of a proton facility were discussed. Design of photon therapy bunkers was covered in a refresher course, and proton therapy was also addressed in a number of proffered papers. The key issues identified for radiation protection in radiotherapy departments (applying to all types of radiotherapy) can be summarised as follows:

- It is essential to have a good understanding of the basic physics of the different components of the beam (primary and scatter) in order to get good dose accuracy.
- The development of a good quality assurance system is essential for ensuring quality and avoiding errors.
- It is important that lessons are learnt from any errors that do occur, including treatment errors and near misses and that, where possible and appropriate, these are disseminated to the wider radiotherapy community.
- Out-of-field (peripheral) doses and their implications for second cancer risks are becoming of increasing concern and are currently the subject of study in many departments.

8.1.2. Nuclear medicine. Discussions of dosimetry challenges in nuclear medicine formed a central theme. This, along with the earlier refresher course on new techniques in radionuclide therapy set out some of the key current issues for radiation protection in nuclear medicine departments, which can be summarised as follows:

- For PET CT & SPECT it is important that consideration is given to the development and optimisation of CT protocols.
- It has been demonstrated that use of generic dose calculation, as is commonly used, can give large errors when compared with individual dose calculations (based on actual patient demographics, biological factors etc), so this is an important area for further development.
- There are many radiation safety issues for patients undergoing iodine therapy. Specific problems can arise when clinical considerations impact on usual practice, such as patients on haemodialysis or peritoneal dialysis, or patients requiring nursing in intensive care.

8.1.3. Diagnostic radiology. The importance of justification of medical exposures was a major topic of discussion. Debate of the idea that 'the current rapid increase in CT scanning can be adequately justified through the existing framework of referral criteria', was active and interesting. The genesis of the new and interim IAEA BSS, which emphasised the importance of justification, and discussed the difficulties, particularly in defensive medicine or financial conflict of interest, was discussed in this context. There are cultural differences, particularly in division of responsibilities between referrer and radiologist (e.g. a request for consultation or an instruction to perform) but BSS requires consultation between the two. The '3As' were introduced: awareness, appropriateness and audit, and the introduction of ethics into justification as well as health technology assessment was recommended. Many medical staff do not understand the concept of justification, and generally have a low awareness of radiation doses and risks in radiological medical procedures. The 'Choose Wisely' campaign did a survey indicating that (over nine medical specialities) 60% of the investigations deemed unnecessary were in imaging.

The wide range of referral criteria available, and their usefulness in carrying out effective justification, was discussed. The idea of age and sex related justification (i.e. more based on individual risk) was also introduced, in particular because there can be an order of magnitude difference in risk for two patients receiving the same examination. Use should be made of a clinical decision support system as this, along with referral criteria has been shown to reduce CT referral patterns.

There were a large number of submitted abstracts under the area of QA, audit and shielding in diagnostic radiology, with the majority relating to CT scanners; mammographic units; dental radiology and the storage and processing of data. Many concerned measurements of patient doses, including comparisons with diagnostic reference levels, or phantom dose measurements. Developments in shielding calculations, database and audit activity were also described.

The key aspects for the future were considered to include:

- all stakeholders must consider QA, audit and shielding as being important parts of the medical practice itself and not as auxiliary technical activities. It was agreed that standard protocols would be useful;
- the present standards and tools for data storage and processing should be further developed and connected through an automated system , which may provide the 'on-line' control of the physical parameters , to launch correction actions and to refine clinical protocols. Such systems should be interconnected;
- diagnostic reference levels (DRLs) have to be further developed and their use encouraged as tools for optimisation;
- referral criteria have to be integrated into medical practice and decision support tool such as computed-based clinical decision support solutions need to be considered to improve justification.

8.1.4. Paediatric and interventional radiology. Challenges in paediatric and interventional radiology were discussed, highlighting the disproportionate contribution of these examinations to overall risk from medical exposure, and the important issue of balancing radiation dose with adequate image quality—small patient size leads to a need for high spatial resolution and contrast sensitivity. Careful set up of equipment and protocols can help with optimising these procedures. Proffered papers covered a range of topics from staff doses in interventional cardiology to paediatric epidemiology studies. The main issues emerging from the session were:

- Staff doses from interventional, particularly cardiology, procedures can be very high, and there needs to be a greater consensus on appropriate monitoring techniques, particularly for eyes.
- More international effort is required to optimise the protection of interventional staff.
- The radiation protection of paediatric patients is of growing concern, and requires more widespread development and use of referral guidelines, justification, optimisation and staff training.

- International collaborative epidemiological studies will be of great importance in the coming years for better assessing or confirming radiation risks at low doses.

8.1.5. The symposium on 'Medical Exposures, Radiation Risk and the Public' brought together some of the leading experts in the field together with a packed auditorium. The recent work of UNSCEAR in assessing the scale of medical exposures around the world was highlighted, showing the dramatic differences between countries with different healthcare levels. The results of an investigation into the variations in radiation protection frameworks in different countries demonstrated a range of approaches particularly with respect to the staff groups involved. The more successful programmes incorporated diagnostic radiology physicists either within hospitals or regulatory bodies. The use and importance of low dose epidemiology studies was described, and the patient view of radiation exposure, focusing on the need for clear communication not only with the patient but between the various staff groups involved in their care was presented.

8.1.6. A forum on global healthcare perspectives brought together representatives from a number of countries, and addressed the challenges and opportunities arising from new healthcare technologies, described the IAEA Programme of Action for Cancer Therapy, discussed new technologies in radiotherapy, particularly conformal therapy, and identified the challenges for justification in diagnostic imaging, and the importance of education and training in this area. Safety culture within the medical sector was discussed, and it was seen as needing to be embedded at all levels: international, national, professional societies and local practice. The key points arising from this forum were:

- The usefulness of global referral guidelines in resource-limited settings.
- The health technology assessment of medical devices which use radiation should be the same as for drugs with respect to safety and efficacy, and only be introduced if benefits outweigh risks.
- How can we ensure safety culture and implementation of modern radiotherapy developments in resource-limited developing countries? There is a need to enhanced knowledge, skills and safety approaches, and education and training is a priority.
- Global agencies and industry need to be engaged to come up with adaptive technologies, especially disease adapted technologies.
- A suitable infrastructure is necessary for implementation of modern technologies in developing countries.

The second forum was on the role of the medical physics expert, and captured the following key points:

- Medical physics is now included as a profession in ILO.
- It should be emphasised that medical physicists are health professionals.
- Revised International BSS of IAEA has significant requirements for medical physicist and it covers most areas of application of radiation, not only radiotherapy.
- The International BSS introduces the 'qualified expert' in a relevant field of specialisation such as medical physics, whereas the draft European BSS uses the term 'medical physics expert'.
- In large part of the world in Asia, Africa and Latin America, there are no requirements of medical physics experts, even though there are requirements for medical physicists.

- Patient protection falls within the responsibility of a medical physicist and staff protection under qualified expert/RPO/RSO.
- The survey among many Asian countries shows that roles and responsibilities of medical physicists are similar to those as specified by AAPM and IAEA.

8.2. Challenges for the coming years

The key issues discussion session for the medical area brought together panellists from a number of disciplines, together with representatives from each of the most recent Regional Congresses. The key issues highlighted were seen as the key challenges for the future, and can be summarised as follows:

- Communication is probably the biggest single issue needing to be addressed. This includes communication between different professional groups; with patients; with regulatory bodies and with manufacturers. Successful communication will underpin many of the points below, and this includes high quality training and education programmes.
- Awareness and concern regarding the radiation risks associated with expanding use of CT technology is growing.
- Justification of diagnostic exposures, particularly CT examinations and paediatric exposures, was a recurring theme throughout the week. Tools are available to aid with this but need to be disseminated more widely and used more effectively. Training is essential to this task.
- The importance of radiation protection keeping pace with emerging new technologies has also recurred during the congress, and the challenges this gives for both dosimetry and optimisation need to be addressed.
- The radiation protection challenges within medicine in the developing world need to be more clearly recognised, along with the fact that priorities may be different to those in more developed countries.
- There needs to be a continuation of the current growth in harmonisation of training standards for professional groups engaged in work involving medical use of radiation.

9. Area 8. Planned exposure situations: radioactive waste management

Radioactive waste management was included as a scientific area at the IRPA conference under ‘Planned Exposure Situations’. Papers on this topic were presented during two technical sessions and two poster sessions. The first technical session and corresponding poster session covered waste management policy, standards and pre-disposal management. The second technical session and corresponding poster session dealt with public exposure assessments and safety cases. In keeping with the theme of the conference, namely ‘Living with radiation, engaging with society’, there was also a symposium on stakeholder engagement in radioactive waste management. In addition, there were two refresher courses on post-closure safety assessments: one for near surface disposal facilities and one for deep geological disposal facilities.

9.1. The current state of knowledge

9.1.1. Policy, standards and pre-disposal management. Presentations and posters on this topic addressed forthcoming ICRP recommendations for geologic disposal of high-level solid radioactive waste, optimisation and exemption from regulation.

Optimisation of protection received considerable attention during the development of the ICRP recommendations on radiation protection in deep geological disposal. It is also easier and better to optimise radiation protection systems during the earlier years of development of such facilities. The scope of these ICRP recommendations is now much wider. They cover not only the human exposures (public and worker) but also exposures of other living organisms, and address all the phases of a geological disposal facility, from site selection and design, through construction and operation, to the post-operational phase, initially with oversight of the facility and then with no oversight.

There seems to be a general trend and need to provide for simple and pragmatic approaches to clearance and exemption criteria. This was evident from a presentation reviewing the UK exemption regime, as well as from presentations and posters from various other countries and organisations. It was, however, also evident that a need exists for countries to work together on international legislation and uniform standards when it comes to some aspects of clearance and exemption. A good example here is the UK and the Nordic countries that are working on uniform standards for the North Sea NORM situation, aiming at least to understand why there are differences between the exemption and exclusion criteria applied in the various countries.

9.1.2. Public exposure assessments and safety cases. The second waste management topic focused on public exposure assessment and safety cases. Several specific examples of assessment approaches were presented, as were various aspects of safety cases.

The presentations and posters showed that the methodologies and models required for public exposure assessments and safety cases are largely available. They range from simple, generic screening tools to complex, site specific methods and models, many of which are probabilistic.

Which of the available tools is appropriate depends on the nature and purpose of the assessment. In the presentations and posters there were examples in which simple conservative modelling was sufficient for an initial exposure or safety assessment. There were also examples where more complex and realistic models were needed because the results were to be used in decisions on the siting, design or operation of a particular facility that produces or manages wastes. In these latter cases it was found to be important to use site specific data, rather than relying on compilations of generic parameter values, and if possible to validate models by comparing their predictions with actual measurements.

The presentation on retrieval of wastes from an old store showed the value of simple measures to reduce contamination, as well as the need for sophisticated equipment built specially for the task. The message here was that optimisation can be as much a result of practical experience and common sense as of advanced engineering or mathematical modelling.

A number of the posters addressed environmental surveillance programmes. These showed the importance of establishing baselines for radionuclide concentrations in the environment, dose-rates and people's habits, then following trends with time. They also illustrated the comprehensive nature of surveillance programmes for various types of facilities and the low doses to the public to which these facilities give rise.

9.1.3. Stakeholder engagement in waste management. At the symposium participants discussed stakeholder engagement for decisions on the long-term management of solid radioactive wastes, particularly decisions on the siting and design of geological disposal facilities. An issue that arose in the discussion was how to deal with differences between evidence-based science and the views of wider stakeholders. This sort of situation is arising in France on the question of how to make emplacement of wastes in a geological disposal facility reversible. Safety experts and lay people tend to have different views on the extent to which emplacement should be made reversible. It had been concluded in France that it is desirable to bring together these two types of stakeholders to frame the problem, before seeking technical solutions.

In Sweden there had been differences of views on corrosion of copper canisters. These had been aired at meetings involving national and international experts, NGOs and other stakeholders, where R&D findings had been discussed and further R&D requirements identified. The matter was now between the regulator and the implementer of geological disposal. In the UK there was a situation where a small number of geologists held strong views that a particular area was unsuitable for a geological disposal facility. It was suggested that one way to deal with this was to obtain the views of a much larger number of geologists and ascertain the majority opinion.

Another discussion issue was how to handle the differing views of local stakeholders and those who live further away from a site for a geological disposal facility. One example of this situation was the Waste Isolation Pilot Plant (WIPP) in New Mexico, USA. The community local to WIPP was supportive of the facility throughout the process of siting, constructing and licensing it. Objections tended to come from those who lived in other parts of New Mexico. The matter was resolved when a federal law was passed allowing WIPP to become a full scale disposal facility. Another example was the planned 'national debate' in France on reversibility for geological disposal, which will involve national and local people, from expert and lay backgrounds. In Sweden there are different levels of support that are considered acceptable: 70% at local level, 40% at national level.

Hearing all the discussion on successes and difficulties in implementing geological disposal, a questioner from a country that has yet to begin a nuclear power programme asked whether it is important to consider radioactive waste management at an early stage. The answer from all the speakers was a resounding 'yes'—the sooner the better.

9.2. Challenges for the coming years

The application and further development of radiological protection standards for deep geological disposal of radioactive wastes is one of the key challenges for the future. In several countries, geological disposal programmes will move from research to implementation over the next few years. The new recommendations from ICRP on geological disposal will need broad discussion before they can be fully understood and interpreted for practical use. The nature of optimisation for disposal facilities is likely to remain an issue, as is ensuring oversight of disposal facilities after the operational period.

With the adoption of new IAEA and EU Basic Safety Standards, much of the debate over standards for exemption and clearance may be over. However, there will inevitably be practical issues to resolve.

Effort on methodologies and models for public exposure assessments and safety cases is likely to shift from development to selection of the best tools for application in specific situations. Acquisition of site specific data and validation of models for specific sites will continue to require attention. In the case of environmental surveillance programmes, the challenge could well be how to reduce costs while still providing the information needed by both the technical community and the public.

While it is essential to address stakeholder concerns, this continues to present challenges to decision makers. One is how to address scientific understanding and social values simultaneously so as to reconcile opposing opinions. Another is how to deal with the different views of various groups of stakeholders. For example, the communities near a proposed geological disposal facility may hold one set of views about its inventory, design, operation and closure, while people living further away hold quite another.

10. Area 9. Emergency exposure situations

Area 9 included three technical sessions and a symposium, and addressed emergency preparedness and response, consequence management, and lessons learned and new threats.

10.1. The current state of knowledge

10.1.1. Emergency preparedness and response. Presentations and discussions of this topic were comprehensive, addressing the technical basis of preparedness and response, radiation protection principles and criteria, protective actions, and decision making as well as future challenges.

Presentations addressed various aspects of preparedness for response, including voluntary emergency worker training to supplement state and local resources for emergency response through the use of local, trained and registered volunteer radiation professionals, international cooperation to train qualified people to take part in emergency response a methodology to plan in a systematic way actions to protect the population in the long-term phase of response to an emergency situation, prior to start the recovery phase. Another more specific topic of discussion addressed the long-term management of contaminated freshwater bodies and catchments.

10.1.2. Consequence management. Several key aspects of consequence management were addressed in these discussions. These included monitoring and medical management of a large population during a radiation emergency, national policy for risk management during the post-accident period following a nuclear accident, and the analysis of a variety of biodosimetric tools for adaptation to different mass casualty scenarios in case of a large-scale radiological emergency.

10.1.3. Lessons learned and new threats. This topic included discussions of lessons from several key areas and described some emerging issues. Experience from other planning and preparedness situations was discussed, with focus on nuclear security arrangements for a large international sporting event, discussion of an exercise assuming a malicious act involving the release of radioactive materials in an urban setting, and experience and lessons from large fires in facilities housing large quantities of unsealed radioactive materials. Lessons in training and calculation approaches was also discussed, focusing on difficulties of some models to provide representative dose estimations in case of terrorist attacks involving dispersion of radioactive contaminants, and the development of training materials for first responders in catastrophic emergencies as well as proposals to overcome existing differences in some national materials for such disaster management training.

10.2. Challenges for the coming years

For the coming years, the participants identified several aspects of emergency management that remain challenging. The new ICRP approach to optimisation of protection in emergency exposure situations was to a certain extent implemented in various countries during the Fukushima NPP accident, but much further assessment of this approach and its interpretation for implementation is needed. In practice, the need to adapt emergency preparedness and planning to this new approach will require that national policy and practice, in particular the performance and output of decision support systems, will need to be revisited. Specifically, malevolent acts have presented challenges to modelling and decision support software, and given the national emphasis placed on preparedness against such acts these tools will need to be improved. As a result of this evolution, there is also a clear need to revisit training and exercising approaches.

11. Area 10. Existing exposure situations

The new ICRP concept of *existing exposure situations* covers a range of situations. These were covered during the IRPA13 Congress in three technical sessions, one symposium and one refresher course, in addition to a number of posters covering various aspects of this area.

11.1. The current state of knowledge

11.1.1. Exposures due to natural radiation and NORM. Natural radiation and NORM are ubiquitous and practically all countries have challenges related to safe NORM management and waste disposal. NORM is found in products, by-products, residues and wastes from a range of industries and can contribute significantly to human and environmental doses. The difference between planned and existing exposure situations when it comes to NORM is not well defined. It is clear that many NORM industries could be considered planned exposure situations, e.g. the oil and gas industry and a variety of mineral extraction industries. On the other hand, there are a number of abandoned NORM sites around the world that should clearly be regarded as existing exposure situations with respect to decisions on future regulation and management. A good principle could be to define all operational NORM sites as planned and all abandoned NORM sites as existing exposure situations. Enhanced levels of NORM can also be a challenge in commodities like building materials, food, drinking water, cosmetics etc leading to increased external, inhalation and ingestion doses to the public. There is a need for international harmonisation of trade limits for NORM in commodities.

Cosmic radiation is a particular challenge when it comes to air crew and astronauts since it is not possible to modify the source. For longer space flights, e.g. to Mars, solar particle events is of particular concern since it produces high energy protons that would cause high personnel doses. Mathematical and voxel models are valuable tools to calculate astronaut doses and the necessary specifications for shielding material on space flights.

11.1.2. Exposures due to persistent radioactive contamination from accidents. Accidents involving dispersion of radioactive material can lead to situations with decades of persisting radioactive contamination of large territories, like the Chernobyl and Fukushima NPP accidents. This causes challenges for the whole society such as public health and welfare, safe food production, socioeconomic aspects, waste generation from remediation, environmental impacts, information and communication issues and community sustainability. Given the duration of contamination and the complexity of such situations, it is important to take a whole community approach to mitigate the consequences of an accident. Experience, for example in Norway and Belarus, has shown that it is possible to continue to live, work and produce food in moderately contaminated regions given a good combination of countermeasures, local involvement and empowerment, and information and communication strategies. Agricultural countermeasures such as clean feeding, Prussian blue and live monitoring of animals have proven successful as opposed to food bans and discarding which are both more expensive and very unsatisfactory to the food producers. Local monitoring and information stations open to the public are key to building local trust and assist in self-help measures that would empower the affected people to deal with the situation. Radiation and health experts should engage in a long-term cooperation with people in affected areas (local administrations, health professionals, teachers, various specialists, general public) to assist them in finding solutions to their challenges. It is also important to combat stigma towards people and food products through education and better communication. Pre-disaster preparedness work will help build resilience in the late phase recovery towards the construction and acceptance of a new ‘normality’.

11.1.3. Exposures due to nuclear legacy. Nuclear legacy sites are another situation of existing exposure with a need for remediation, safe waste management and final repository solutions. Nuclear legacy sites are e.g. disused nuclear facilities, nuclear weapons testing areas, abandoned uranium mining and milling sites, waste tailings, temporary storage sites for spent nuclear fuel and radioactive waste etc. Many countries around the world have nuclear legacy sites, in particular related to the mining and milling of uranium. The operation of the sites was typically initiated at a period in history when regulations were insufficient to deal with the later closing and decommissioning of the site. Today, most countries lack adequate regulations to deal with the existing complex situation at nuclear legacy sites. There are challenges related to both worker conditions, public and environmental exposures, waste handling and disposal, and nuclear safety and security. To deal with these sites is a long-term engagement that involves site specific surveys, risk and environmental assessments, optimisation of remediation options, balancing short and long-term risks, and developing new regulations that addresses the specific challenges. In some countries, the development of strong and independent regulatory bodies needs to be part of the long-term effort to find final solutions that are safe and acceptable for people and the environment. Many countries would benefit from an increased international cooperation and exchange of experience on these issues, e.g. through the IAEA International Forum on the Regulatory Supervision of Legacy Sites.

11.1.4. Exposures due to radon. There is strong epidemiological evidence that radon causes lung cancer in both smokers and non-smokers. This has been proven in large epidemiological studies with a detailed stratification for smoking history. The absolute risk for lung cancer is much higher for smokers, but the relative risk is the same for smokers and non-smokers. Most radon-induced lung cancers occur at low to moderate concentrations. There may also be other diseases induced by radon, e.g. childhood leukaemia, and more research is needed on possible other health effects.

Knowledge about the efficiency of different prevention techniques is available and it is also proven that the efficiency and cost-effectiveness of prevention is much higher for new buildings than existing dwellings. Imposing radon prevention requirements in new building codes is thus efficient to reduce country averages in the long term. There has been concern whether the trend in designing passive houses would increase the indoor radon concentrations, but testing has shown that proper passive house constructions will give low radon concentrations indoors. Again, new building codes and the correct execution of these are key to successful radon prevention so proper training of building professionals should be one of the priority areas for the future.

For existing dwellings the challenge is more complex. National radon surveys, geological studies and increased public awareness of the value of measuring radon in homes are important to identify dwellings with increased radon values. However, relatively few people will actually remediate their home even if they have high measurements, and smokers are less likely to do so than others. All countries should therefore develop national radon policies and action plans where a range of tools and incentives should be implemented across different sectors for a coordinated and long-term effort in reducing the exposures to radon for the general public.

Improved information and radon risk communications, not only with the public but also with other stakeholders such as local government, building industry, medical professionals etc should be an essential component of a successful national action plan against radon. Joint efforts across sectors are important and, for instance, joint campaigns for smoking cessation and radon prevention could be very effective.

When it comes to measurements, we have good QA for long-term measurements of radon that take into account the diurnal and seasonal variations, but proper measurement protocols for short-term measurements should also be developed. This is of particular interest when buying or selling houses when a long-term measurement cannot be performed.

11.2. Challenges for the coming years

All these areas of existing exposure situations share some common challenges for the future. First of all, the risk assessment for people and the environment is not straight forward since it depends on a number of parameters with site specific values. The risk assessment methodology and tools should be 'as simple as possible, as complex as necessary'. This sounds simple, but is challenging in practice so more guidance is needed. These issues would also benefit from better international harmonisation and the sharing of lessons learnt in dealing with these challenges. It will also require a long-term engagement of experts and decision makers, and a good communication and/or cooperation with the public to achieve a significant reduction in exposures from existing situations.

12. Area 11. Protection of the environment

This subject has risen in visibility in recent years, its inclusion as one of the 12 scientific areas in the IRPA13 Congress demonstrating the importance that it now holds for the radiological protection profession.

12.1. The current state of knowledge

Environmental radiation protection was discussed in a symposium, a technical session and a poster session; and was also the subject of a refresher course. The submitted papers covered a wide range of topics, although some were more related to monitoring and mainstream radioecology. Whilst environmental radiation protection draws on radioecology, and may benefit from monitoring data, it is different from both those areas. Environmental radiation protection is about defining protection purposes and targets, develop methodology that is fit for purpose, and assemble or generate—as appropriate—input data to support the methodology. There has been a swift progress in this area over the last ca. 15 years, and it has been included in the system for radiation protection as outlined by the International Commission on Radiological Protection, ICRP (in Publication 103, 108 and 114) and underpinned by a large number of national and international research projects.

Large databases have been assembled that support environmental assessments and the establishment of methodologies to derive protection goals—and to demonstrated compliance with such goals. Most systems centre on a 'reference' concept, such a reference being a geometrical representation of an 'organisms', a generically defined organism, or a specific species with defined properties and life-history. However, it is also clear that there are substantial data gaps in a number of areas, i.e. transfer factors for certain combinations of radionuclide/ecosystem/organism, or effects data for a number of ecologically relevant organisms or organism groups. A number of the submitted papers addressed various approaches to better model, or directly determine dispersion as well as distribution coefficients between the organism and the environmental media, also involving more refined biokinetics.

Much attention has in the past been attached to RBE for various types of radiation (notably alpha) for environmentally relevant endpoints. Whereas—again—data are patchy, careful examination of available information seems to indicate that derived weighting factors would not be much different—if at all different—from those underpinning the system for human radiation protection.

Additional uncertainty stems from the difficulties in relating the effects observed in individual organisms to responses at the population level, not to mention at the ecosystem level.

At levels of environmental radiation that are moderately elevated to background, effects at the population and/or ecosystem level may be insignificant *per se*, or masked or completely offset by compensatory mechanisms. Non-targeted effects may affect the population dynamics and ecosystem resilience in a manner that is currently very little understood. Whilst the ultimate scientific aim may be to understand the 'ecosystem effect' of radiation and to be able to use what has been termed an 'ecosystem approach' to environmental radiation protection, knowledge in this area is presently by far insufficient to guide any efforts aimed at protection of the environment. For foreseeable time, such efforts will have to rely on establishment of dose-response relationships established for 'references' as discussed earlier, whilst noting the uncertainties surrounding such assessments.

Encouragingly, as demonstrated during the symposium and further during the refresher course, protection systems have already been successfully used in a number of cases, including assessments of existing sites, development of national systems, and in supporting strategies in to communicate impact assessments to a non-technical audience.

12.2. Challenges for the years to come

The challenges for the years to come stem directly from the gaps in scientific knowledge, identified in the previous section. In addition, there are a number of aspects of the system of protection and its application in different situations (including the different exposure situations as defined by the ICRP) that need to be further elaborated.

Regarding missing data and uncertainties there is need to determine transfer factors in a number of less well-studied ecosystems and for certain organisms, that in a particular assessment context may be relevant and important. Even in some well-developed databases, e.g. as laid out in ICRP Publication 114, a large fraction of the concentration ratios have been inferred. Whilst this has been done using a logical and transparent methodology, it is presently not possible to benchmark the inferred data against actual observations. Similarly, there are data gaps in the effects data (ICRP Publication 108); indeed, the data gaps that become apparent by the systematic assembly of data for use in assessments and for the purpose of environmental protection, provide very clear directions for future research.

The linkage between effects that can be readily demonstrated in individual organisms and effects at higher levels of biological organisation (population, ecosystem) requires further attention and study. Possibly, a new radioecological approach—emphasising the *ecology* element—could be helpful here. Such studies would also have to consider the relevance and relative contribution from any non-targeted effects to ecosystem responses.

Obligations to comply with environmental goals and targets stem from both national legislation and international agreements, either these are binding or incentive in nature. The implementation of the system for protection, whilst incorporating a reasonably precautionary approach, needs to be commensurate with the risks. International research projects have developed 'screening criteria', usually in the form of environmental dose-rates that have been derived from effects studies. The use of such screening criteria, in combination with robust but simple assessment methodologies, to exempt certain activities from further assessments would help in focusing efforts on activities of real or potential concern. This would greatly assist in implementing environmental protection programmes without risking that any major situation of real or potential concern be overlooked. For the situations of concern, the system as it has emerged over the last years, provides a reasonably robust framework to guide decision making in relation to all effects and risks associated with planned, existing and emergency exposure situations.

Finally, there is a need to keep the radiation protection system simple. Whilst the system for human radiation protection has been simplified and clarified in Publication 103, it is necessary to avoid it being overly complicated by inclusion of the environmental component. The principles of justification and optimisation (guided by environmental reference levels) apply also to environmental radiation protection. Further development of the radiation protection systems to explain how the principles of justification and optimisation can be used to address environmental issues would assist the stakeholder interaction in this area.

13. Area 12. Fukushima Daiichi nuclear accident

The accident at the TEPCO Fukushima Daiichi nuclear power plant was a significant, additional disaster on top of the East-Japan earthquake and subsequent tsunami. The effects of the radioactive contamination that was spread over large areas in Japan, and that has been measured all over the northern hemisphere, will be with us for years to come. In view of the importance of this accident to the Japanese people and to the world, and of the lessons that the radiological protection and emergency management communities are interested in and are morally obliged to learn, the 13th IRPA Congress dedicated five sessions, including a major plenary session, to these topics.

13.1. The current state of knowledge

As of summer 2012 there remain approximately 14 000 people with restricted or no access to their homes in affected territories having significant contamination levels, covering an area within on the order of 60–80 km of the Fukushima site. Contamination levels are being measured and are increasingly well known, and a road-map for recovery is being implemented and continually updated.

Several estimates of public exposures resulting from releases have been developed, and suggest that individual public exposures remain low. Estimates suggest that for most of the exposed members of the public, those evacuated and those who sheltered in place, doses were below about 20 mSv. This represents the sum of doses received during the main accident period, i.e. the first month or so, and doses for the rest of the first year following the accident (i.e. until 11 March 2012). A conservative estimation by the WHO, not accounting for shielding or countermeasures, suggests the highest population doses in a band from 10 to 50 mSv.

Exposures of workers at the Fukushima reactor site are below emergency exposure situation guidelines (250 mSv) for all but 6 of the 20 000 TEPCO and contractor employees who have worked at the site since the accident, the highest dose being 678 mSv to one worker.

Public concerns remain high, and public trust in officials is extremely low. Many stakeholder groups are forming to share concerns and to identify their own solutions.

Over a year after this accident began, a number of relevant radiological protection and emergency management issues and observations have been identified. For example; sheltering for long periods was not envisioned or planned for as a significant emergency management measure, and posed many challenges; radiation risks are not well understood by either the broader public or by the university or medical communities; public concern is very strongly focused on the protection of children; and emergency management tools and approaches, in particular as related to international aspects, need improvement and a better level of coordination and harmonisation. These have a strong influence on the issues that will remain challenging for emergency management in the future.

13.2. Challenges for the years to come

The Fukushima Daiichi reactor accident has highlighted several areas where lessons had been previously identified but not sufficiently addressed, as well as some aspects of emergency management and response that were previously known but which were particularly highlighted by the circumstances of this accident. All of these pose challenges for the coming years, and will need national and international focus to arrive at sustainable and acceptable approaches for emergency and recovery planning and management.

In terms of emergency planning, the accident demonstrated that preparations for extreme circumstances are needed. Although unlikely, large and long-duration releases are clearly possible, and emergency planning and preparedness will need to be flexible and resilient enough to cope with such circumstances. This involves many different aspects of preparations. Plans and exercises will need to be reviewed and updated to better prepare for such situations. Locations and capabilities of off-site emergency response centres and equipment storage depots will need to be reviewed and improved as appropriate. Procedures and approaches to ending sheltering and returning people to their homes will need to be reviewed. Large-scale capabilities for environmental contamination and dose-rate monitoring need the ability to be quickly and broadly mobilised. Emergency planning zones as defined in current emergency response plans need to be revisited to assure that they meet their intended purposes. Spent fuel storage facilities, and perhaps other previously-assessed facilities, need further review to assure that their possible accident scenarios are appropriately taken into account. The huge number of questions from the public and from media poses significant staffing challenges to radiological protection authorities and emergency response organisations, particularly for smaller countries. There is a need for national radiological protection authorities to be ready to provide practical advice in a variety of areas, such as monitoring of food and goods coming from affected territories.

In terms of emergency response, the accident has clearly demonstrated the need for more communications, more transparency of decisions, and more stakeholder involvement. This is particularly of importance as accident response needs shift from urgent protective actions to recovery activities. Evacuated populations want to return home, and there is a need to develop agreed criteria for allowing this. Those living in contaminated territories want to be sure they are appropriately protected, and are appropriately protecting their children—for this they need clear governmental infrastructures and actions, information, and tools to ‘optimise’ their self-help protection actions. There is a clear need to be ready with sufficient resources to hold detailed discussions with affected populations to appropriately address their concerns. At the same time, broader national discussions and diffusion of information need to take place to address the concerns of those beyond the affected areas who may have family in or buy goods or food from the affected areas. The need to better harmonise emergency management criteria and approaches, and coordinate emergency management actions and decisions was also clearly illustrated by national and international responses. The large-scale social disruption caused by such an accident needs to be considered as a driver of prevention and response decisions. Recovery is at least as important to plan as preparedness, and an active public and governmental safety culture would be of great value. All of these aspects have posed significant challenges, particularly with regard to maintaining trust in government.

In terms of the system of radiological protection, the Fukushima accident has highlighted several areas where clarification and further explanation is needed. Some of these areas were previously known, such as the need to better explain the use of collective dose, to simplify and better explain the various quantities and units used, and to achieve better consistency among the various criteria used to manage exemption under different circumstances. In addition, however, the accident has heightened the need for clear recommendations for the different protection criteria needed for various types of workers in an emergency situation (e.g. for life-saving actions, for nuclear worker ‘normal’ recovery actions, for others working in contaminated areas, etc), concerning the need for more specific recommendations for the protection of children, and for reconsideration of the aspects considered for the justification of heavy countermeasures such as evacuation or the cessation of agricultural activities. It should also be noted that the

Fukushima Daiichi nuclear power plant accident has clearly highlighted that there is a broad lack of understanding of the system of radiological protection outside of the radiological protection community, most significantly among the public and decision makers. This is not new, but continues to be an challenge of importance.

In terms of the nuclear industry and nuclear regulation, the Fukushima NPP accident should challenge all nuclear operators and regulators around the world. Three Mile Island taught us about the importance of human factors, procedures and the man/machine interface. Chernobyl gave rise to the concept of Safety Culture and the importance of transparency. The Fukushima NPP accident highlighted the need to more effectively prepare to address severe natural risks and common-mode failures at multiple-unit sites, and in the face of such extremely unlikely events to build in resilience of response capabilities. Given the potential long-term contamination of surrounding areas after a severe nuclear accident, the question becomes how this long-term contamination can be avoided. Enhancing the design of the reactors is a first step, however in addition to this enhancement, picturing the 'unimaginable' is the second step. This is by definition impossible to predict at the time of design, and as such the only possible answer lies in the resilience of the organisational systems.

14. Conclusions

The IRPA13 Congress was an unconditional success on several levels. From the scientific and technical standpoint the Congress' presentations, posters and refresher courses represent the state-of-the-art in radiological protection science and practice. As can be seen even from this brief summary of the 12 scientific areas addressed, radiological protection is an active, vibrant field that continues to evolve and innovate, and to identify and begin to address emerging challenges. The profession has a healthy view of what it knows and does not know, and continues to strive to better understand the intricate and complex aspects of radiation biology and physics that our profession uses to best protect people and the environment.

But this is only part of the story, as illustrated by the IRPA13 Congress theme 'Living with radiation, engaging with society'. Radiological protection choices and decisions are informed by science and its uncertainties, and take into account social values and their diversity. This is well illustrated in determining the optimum protection strategy that will maximise the benefits of activities or actions that involve exposure to ionising or non-ionising radiation, and will reduce, to a level as low as reasonably achievable, any associated detriments. To capture the complex nuances of these types of choices and decisions, the IRPA13 Congress included several opportunities to hear from stakeholders and to share practical experience among those involved in such situations, and to engage with the next generations of those who are starting to be or may be involved in radiation protection in the future.

Finally, the IRPA13 Congress was a great step in helping IRPA to practically and explicitly represent the voice of the radiological protection community. A key objective of the Congress was to identify the profession's view of the state of current knowledge, and the challenges for the coming years. These views were collected from those attending the Congress in person, but also to a certain extent from those attending parts of the Congress electronically. Although it is sure that the themes documented here do not represent a complete story of what we know or what challenges remain, it is sure that these views do broadly represent most of the key aspects that are seen by the profession as important. This was at least in part assured by the programmatic structure put in place to collect this information during the Congress, and by the web-based review of the draft conclusions.

In order to continue the debates begun during IRPA13, the abstracts, papers, PowerPoint presentations and posters from the Congress will be stored on the IRPA website (www.irpa.net) for consultation and reference. In addition, podcasts of key sessions will be available so that these views can continue to be spread, discussed and refined by members of our profession, ready for the next 'snapshot' of where we are at the IRPA14 Congress in Cape Town, South Africa, in 2016.

Acknowledgments

The IRPA13 International Congress Programme Committee would like to thank all the presenters and participants in the IRPA13 Congress for having made it a smashing success! Your enthusiastic participation, in particular in assisting us with this paper by providing comments on the web, is extremely well appreciated and we would like to thank all those who contributed in this process.

In particular, we have drawn these summaries from a variety of sources, including session chairs and rapporteurs, and would like to thank all those have who helped to pull this report together.

The ICPC would also like to thank the IRPA13 International Congress Organising Committee, and in particular Roger Coates, its Chair, for their contributions to the Congress and to the development of this paper.

The views expressed are those of the authors and not necessarily of their organizations.

Appendix A

A.1. IRPA13 International Congress Programme Committee (ICPC)

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Appendix B. IRPA13 sessions

Plenary sessions	
P1	Sievert lecture—Richard Osborne
P2	Underpinning science: state of the art
P3	Engaging with society
P4	The system of protection
P5	Lessons and challenges following the Fukushima NPP accident
Key issue discussion sessions	
KIDS 1	Underpinning science
KIDS 3	The system of protection
KIDS 4	Stakeholder engagement
KIDS 6	Nuclear industry
KIDS 7	Exposures in medicine
Technical sessions	
TS 1a	Radiation biology
TS 1b	Epidemiology
TS 1c	Human health effects and risk factors
TS 2a	External exposure assessment
TS 2b	Internal exposure assessment
TS 2c	Biological dosimetry and modelling
TS 2d	Instrumentation and measurement I

TS 2e	Instrumentation and measurement II
TS 2f	Metrology and dosimetry
TS 2g	Numerical and computational dosimetry
TS 3a	RP system: evolution and implementation
TS 3b	RP system: regulations and standards
TS 3c	RP system: management and culture
TS 3d	RP system: education and training
TS 4a	Experience in stakeholder engagement and decision making
TS 4b	Processes, methodologies and tools in stakeholder engagement
TS 5a	Non-ionising radiation
TS 6a	RP issues in the nuclear fuel cycle
TS 6b	Decommissioning
TS 6c	NORM in mining and industry
TS 6d	Non-nuclear industry, research, transport and security
TS 7a	Radiation protection in radiotherapy
TS 7b	Radiation safety issues in nuclear medicine
TS 7c	QA, audit & shielding in diagnostic radiology
TS 7d	Justification of medical exposures
TS 7e	Radiation protection challenges in interventional & paediatric radiology
TS 8a	Waste management: policy/strategy & standards, pre-disposal, clearance & exemption
TS 8b	Waste management: discharges & public exposure assessment, waste storage & waste disposal facilities
TS 9a	Emergency preparedness and response
TS 9b	Emergency consequence management
TS 9c	Emergencies: lessons learned & new threats
TS 10a	Existing exposure situations due to NORM and natural radiation
TS 10b	Existing exposure situations due to accidental contamination and nuclear legacy—long-term management and remediation
TS 10c	Radon
TS 11a	Protection of the environment
TS 12a	Fukushima: overview and dispersion of radioactive material
TS 12b	Fukushima: emergency planning and communications
TS 12c	Fukushima: monitoring and dose assessment

Poster sessions

Each poster was displayed for two days—either Monday/Tuesday or Wednesday/Thursday

PS A	Monday
PS B	Tuesday
PS C	Wednesday
PS D	Thursday

Symposia

S3.1	Radiation protection culture
S4.1	Affected populations experiences
S4.2	Teaching radiation protection in schools
S7.1	Medical risk and the public
S8.1	Stakeholder involvement in waste management
S9.1	Medical countermeasures against serious radiation exposure
S10.1	Radon exposure

S11.1	Protection of the environment
S12.1	Japan HPS Fukushima symposium
Fora	
F2.1	Dosimetry and measurement ICRU
F3.1	Ethics and values in radiation protection ICRP/NEA
F3.2	Legal aspects of radiation protection INLA
F6.1	Worker education and training IAEA/ILO/NEA
F6.2	The role of radiological protection professionals in the security of radioactive sources WINS
F6.3	Nuclear industry forum WNA
F7.1	Role of the qualified expert in hospitals IOMP
F7.2	Global health care perspectives IAEA/WHO/PAHO
Refresher courses	
RC1	Biological effects of radiation
RC2	Use of the INES scale to communicate the safety significance of nuclear or radiological events
RC3	Radiation detriment: evolution of its estimation and its role in the RP system
RC4	Optical radiation safety
RC5	Design of medical facilities: radiotherapy shielding design
RC6	Conducting effective stakeholder involvement
RC7	Internal dosimetry
RC8	Training workers in RP for a safer work environment
RC9	EMF measurements for health and risk assessment
RC10	Protection issues for novel radionuclide therapies
RC11	Supporting stakeholder needs for information and facts
RC12	Radiation protection in NORM industries
RC13	Safety and security in the transport of radioactive materials
RC14	Considerations in estimating public doses from nuclear facilities
RC15	Radiation protection and pregnancy in the medical environment
RC16	Using new technologies in support of stakeholder involvement
RC17	Optimisation of RP for the decommissioning of facilities
RC18	Introduction to Post-Closure Safety Assessment of near surface disposal facilities
RC19	Emergency management according to new IAEA BSS
RC20	Radiation protection in interventional x-ray procedures
RC21	Introduction to post-closure safety assessment of deep geological disposal facilities
RC23	Optimisation of radiation protection for radon exposure in homes
RC24	Radiation protection of the environment
RC25	Radiation protection & dosimetry in paediatric CT