IRPA12

IRPA

12th Congress of the International Radiation Protection Association (IRPA12):

Strengthening Radiation Protection Worldwide – Highlights, Global Perspective and Future Trends

S.A.R.

IAEA

Pan American Health Organization

WHO

19–24 October 2008
Buenos Aires, Argentina

IAEA
International Atomic Energy Agency

12th CONGRESS OF THE INTERNATIONAL RADIATION PROTECTION ASSOCIATION (IRPA12): STRENGTHENING RADIATION PROTECTION WORLDWIDE — HIGHLIGHTS, GLOBAL PERSPECTIVE AND FUTURE TRENDS

The Agency's Statute was approved on 23 October 1956 by the Conference on the Statute of the IAEA held at United Nations Headquarters, New York; it entered into force on 29 July 1957. The Headquarters of the Agency are situated in Vienna. Its principal objective is "to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world".

PROCEEDINGS SERIES

12TH CONGRESS OF THE INTERNATIONAL RADIATION PROTECTION ASSOCIATION (IRPA12): STRENGTHENING RADIATION PROTECTION WORLDWIDE — HIGHLIGHTS, GLOBAL PERSPECTIVE AND FUTURE TRENDS

STRENGTHENING RADIATION PROTECTION WORLDWIDE —
HIGHLIGHTS, GLOBAL PERSPECTIVE AND FUTURE TRENDS
PROCEEDINGS OF THE 12TH CONGRESS OF THE
INTERNATIONAL RADIATION PROTECTION ASSOCIATION (IRPA12)
ORGANIZED BY THE
ARGENTINE RADIATION PROTECTION SOCIETY
IN COOPERATION WITH THE
INTERNATIONAL ATOMIC ENERGY AGENCY,
THE WORLD HEALTH ORGANIZATION AND THE
PAN AMERICAN HEALTH ORGANIZATION,
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FOREWORD

This publication represents the official record of the 12th International Congress of the International Radiation Protection Association (IRPA), held in Buenos Aires, Argentina, from 19 to 24 October 2008. These international congresses are organized locally by IRPA Associate Societies, and this 12th congress was organized by the Argentine Radiation Protection Society (SAR) in cooperation with the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the Pan American Health Organization (PAHO).

The protection of people and the environment from the harmful effects of ionizing and non-ionizing radiation, while permitting the development and use of radioactive materials and radiation producing devices and technologies for the benefit of society, is a crucial international endeavour. Radiation is present everywhere in the natural environment and there are some industrial activities that lead to increased exposure to these natural sources. The use of radioactive material and radiation producing devices is on the rise in medical diagnostic and therapy procedures. These procedures generally benefit the patients involved, but also present risks to both the patient and medical personnel involved in the procedures. Plans to increase the development of nuclear power will require strong radiation protection programmes in mining, processing, transportation, and the use and disposal of nuclear and radioactive material. Radiation protection faces additional challenges with security screening, responses to potential acts and emergencies involving the release of radioactive material, and other industrial and research activities.

Since 1966, IRPA has promoted and sponsored international congresses to provide opportunities for radiation protection scientists and engineers, as well as researchers and regulators, to present their work and discuss current radiation protection issues.

IRPA also promotes the development of effective radiation protection programmes through the organization of 46 Associate Societies in 60 countries in cooperation with the IAEA through the latter's Model Project for Upgrading Radiation Protection Infrastructure.

The IAEA General Conference took a special interest in IRPA12. On 22 September 2006, two years before the congress, during the 9th plenary meeting of its 50th regular session, the General Conference adopted resolution GC(50)/RES/10 on measures to strengthen international cooperation in nuclear, radiation and transport safety and waste management. After noting the forthcoming IRPA12, the General Conference encouraged the IAEA Secretariat to support the dissemination of information arising from the Congress and to support the participation of developing countries. On 21 September 2007, during the 9th plenary meeting of its 51st regular session, the General Conference

adopted resolution GC(51)/RES/11 on the same topic, which supported the IAEA Secretariat's efforts to ensure the wide participation of developing countries in IRPA12, and urged the Secretariat to take concrete measures to ensure the early dissemination of information. Finally, just a few weeks before the congress, on 3 October 2008, during the 7th plenary meeting of its 51st regular session, the Conference adopted resolution GC(52)/RES/9 on the same topic, which once again supported these actions. This publication has been produced in response to these resolutions.

To address radiation protection challenges, IRPA12's scientific programme was divided into three areas:

— **Epistemological basis of radiation protection**, namely current knowledge of the physics and biology of radiation exposure and its effects, particularly in relation to its scope, experimental methods and theoretical validity;
— **Paradigm of radiation protection**, namely universal conceptual models used to protect people from deleterious health effects due to radiation exposure;
— **Radiation protection in practice**, namely the actual application and use of radiation protection plans and methodologies by practitioners and industries making use of radiation.

Keynote addresses, round table discussions, invited speakers, and oral and poster presentations initiated and encouraged discussion in these areas.

A total of 1382 radiation protection specialists and practitioners attended the Congress, as well as 280 exhibitors and accompanying persons. The attendees came from 90 countries, underlining the great interest in radiation protection worldwide. More than 1500 papers were contributed to the Congress. Approximately 250 papers were presented orally and more than 1000 were displayed as posters. Many individuals from developing countries who had papers accepted for presentation were offered support to attend the Congress. The IAEA, through its technical cooperation programme, provided exceptional support to many young professionals from a large number of developing countries who were thus able to attend the Congress and refresher courses. IRPA offered additional support to other attendees and many more received support from WHO, PAHO, the Nuclear Regulatory Authority of Argentina and IRPA Associate Societies.

This publication presents the highlights of the IRPA12 Congress: the Sievert Lecture, all keynote addresses at the plenary sessions, summaries of the contributed papers and discussions at the topical sessions, as well as conclusions of the conference sessions. The full set of keynote addresses, contributed papers, presentations and refresher courses is available on the IRPA12

(*www.irpa12.org.ar*) and IRPA (*www.irpa.net*) web sites and on the CD-ROM attached to this publication. The global overview of radiation protection provided in this publication is complemented by a discussion of future trends in the area.

EDITORIAL NOTE

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SUMMARY OF THE SCIENTIFIC PROGRAMME

1. GENERAL OBJECTIVES AND ORGANIZATION

The general scientific policy objectives of the 12th International Congress of the International Radiation Protection Association (IRPA12) were the following:

— To encourage all participants to put into practice its motto: "strengthening radiation protection worldwide". IRPA12 focused on the promotion, enhancement and strengthening of radiation protection worldwide through a broad gathering of professionals, rather than through a highly specialized conference aimed at reporting sharp scientific breakthroughs;
— To produce a definite outcome, namely concrete findings and follow-up recommendations that can be implemented.

To attain these general policy objectives, IRPA12 was arranged in three distinct Main Fields, which were divided into 10 Scientific Areas including a total of 38 Topical Sessions. The overall scheme is displayed in Table 1.

2. MAIN FIELDS

The IRPA12 programme addressed the three main fields of radiation protection as follows:

— **Epistemological basis**[1] **of radiation protection**, namely current knowledge of the physics and biology of radiation exposure and its effects, particularly in relation to its scope experimental methods and theoretical validity;
— **Paradigm of radiation protection**, namely universal conceptual models used to protect people from deleterious health effects due to radiation exposure;
— **Radiation protection in practice**, namely the actual application and use of radiation protection plans and methodologies by practitioners and industries making use of radiation.

[1] Epistemology is used in the context of the **C**ongress to refer to the origin, nature, methods, validity, and limits of scientific knowledge on radiation exposure and its effects.

TABLE 1. OVERALL STRUCTURE OF THE SCIENTIFIC PROGRAMME

Main Fields	Scientific Areas	Topical Sessions
I Epistemological Basis of Radiation Protection	I.1 Characterization of Radiation Exposure	I.1.1 External Exposure to Ionizing Radiation
		I.1.2 Internal Exposure
		I.1.3 Biological dosimetry
	I.2 Biological Effects of Radiation Exposure	I.2.1 Effects on Molecules, Organelles & Cells
		I.2.2 Effects on Tissues and Organs (including hereditary and prenatal effects)
		I.2.3 Radiopathology
		I.2.4 Radio-epithemiology
II Radiation Protection Paradigm	II.1 Developing the Radiation Protection Framwork	II.1.1 Evolving International Safety Regime
		II.1.2 National Infrastructures
		II.1.3 Education, Training and Staffing
		II.1.4 Safety and Security of Radiation Sources
	II.2 Developing Protection Policies, Criteria, Methods and Culture	II.2.1 National Infrastructures
		II.2.2 Protection of the Public & Environment
		II.2.3 Occupational Protection
		II.2.4 Protection of Patients
	II.3 Emergency planning, Preparadness & Response	II.3.1 Nuclear and Radiological Emergentics
		II.3.2 Medical Response in Emergentics
		II.3.3 Emergency Afterpath and Recovery

TABLE 1. OVERALL STRUCTURE OF THE SCIENTIFIC PROGRAMME (cont.)

Main Fields	Scientific Areas	Topical Sessions
III Radiation Protection and Safety in Practice	III.1 Nuclear Installations	III.1.1 Nuclear Reactors
		III.1.2 Nuclear Fuel-Cycle Facilities
		III.1.3 Decommissioning and Restauration
		III.1.4 Radioactive Waste Management
	III.2 NIRs	III.2.1 Power Frequency Electric and Magnetic Fields
		III.2.2 Mobile Telecommunications
		III.2.3 Optical Radiation and Ultrasound
		III.2.4 Emerging EMF Technologies
	III.3 Medkine	III.3.1 RP in Diagnostic Radiology
		III.3.2 RP in Interventional Radiology
		III.3.3 RP in Nuclear Medicine
		III.3.4 RP in Radiotherapy
	III.4 NORM in Indutry	III.4.1 Uranium Mining and Processing
		III.4.2 Other Minerals Mining and Processing
		III.4.3 Oil and Gas
		III.4.4 NORM and Radon Issues in Building
	III.5 Other Applications and Practices	III.5.1 Transport of Radioactive Materials
		III.5.2 Industrial, Research Applications and Security Screening
		III.5.3 Radon and the Public
		III.5.4 Flights and Space

For each main field, a background session was held, which provided the status of information on major international issues in these three fields. The keynote addresses held at these background sessions are included in this publication.

3. SCIENTIFIC AREAS

Within the above main fields, IRPA12 focused on 10 Scientific Areas as follows: characterization of radiation exposure; biological effects of radiation; developing the radiation protection framework; developing protection policies, criteria, methods and culture; emergency planning, preparedness and response; radiation safety in nuclear installations; non-ionizing radiation applications; medicine; natural occurring radioactive material in industry; other applications and practices.

4. TOPICAL SESSIONS

The 38 Topical Sessions, as shown in Table 1, addressed the major topics within the scientific areas inside the three main fields.

Keynote speakers addressed the status of radiation protection in each session. A rapporteur summarized relevant findings reported in each Topical Session, covering the more than 1500 contributed papers accepted by the Congress Programme Committee. Around 250 contributed papers were presented orally and the rest were shown as posters. More than 1000 posters were displayed and discussed at three very well attended poster sessions. The content of these contributions, including full papers and presentations are available on the CD-ROM attached to the back of this publication as well as on the IRPA (www.irpa.net) and IRPA12 web pages (www.IRPA12.org.ar).

Each session featured an open forum for ample debate and, as a result, topical contributions were widely discussed. Chairpersons of the Topical Sessions, with the assistance of local Scientific Secretaries, summed up the various outcomes, which were presented in concluding plenary sessions. Their work has been used as the basis for summaries and conclusions of all Topical Sessions provided in this publication. The summaries are necessarily inhomogeneous as they reflect the different attitudes of various session officers. For further details, the reader is referred to the various session officers, whose names are recorded at the end of this document.

Three special Topical Sessions were held: networking in radiation protection, legal implications of radiation protection, and stakeholder

engagement in practice. The first two were round table discussions of specific issues, while the third was presented as a series of papers. The findings of these special Topical Sessions are also summarized in this publication.

5. WORKING LUNCHES

For the first time at an IRPA Congress, working lunches were included, which presented speakers on selected topics. Two issues were discussed, both of great importance in today's global agenda: strategies for radiological security and radiation protection in life extension programmes for nuclear power plants. Their content can be found in this volume.

6. REFRESHER COURSES AND SEMINARS

A comprehensive programme for refresher training on specific radiation protection issues was also part of the Congress, including accreditation by the American Academy of Health Physics. In total, there more than 1000 registrations were received for the 20 courses offered — a record number! The teaching material (full text and presentations) can be found in the CD-ROM and on-line at the IRPA12 (www.IRPA12.org.ar) and IRPA (www.irpa.net) websites.

The 20 Refresher Courses covered the topics listed in Table 2, which also shows their relation to the scientific areas and Main Fields covered. There were also three Updating Seminars with relevant presentations by experts covering the areas of "Radiological Protection of Patients", "Radiation Protection in NORM Industries, Including the Phosphate Industry" and "Radiation Protection in the Nuclear Industry".

7. AWARDS

Two award ceremonies also took place at IRPA12. Professor Christian Streffer (Germany) received the 2008 Sievert Award and presented the traditional Sievert lecture, entitled "Radiological Protection: Challenges and Fascinations of Biological Research". A summary of the Sievert lecture is included in this publication.

Dr. K. Sankaranarayanan (India/the Netherlands) was awarded the 2008 Gold Medal of the Swedish Academy of Sciences in recognition of his long standing work on hereditable radiation effects. The medal was presented by H.E. Arne Rodin, Swedish Ambassador to Argentina.

TABLE 2. REFRESHER COURSES

Main Fields	Scientific Areas	Refresher Courses (RC)
		Title
I ***Epistemological basis of radiation protection***	I.1 Characterization of radiation exposure	*RC-1.* External dosimetry: Dosimetry in new radiotherapeutic techniques
		RC-6. Internal dosimetry: The science and art of internal dose assessment
		RC-12. Early biodosimetry response: Recommendations for mass casualty radiation accidents and terrorism
	I.2 Biological effects of radiation exposure	*RC-2.* Cellular and molecular effects: Non-targeted biological effects of ionising radiation
		RC-7. Epidemiological methods on residential radon and cancer risk
II ***Radiation protection paradigm***	II.1 Developing the Radiation Protection Framework	*RC-3.* Implementing the regulatory authority information system (RAIS)
		RC-8. Managing nuclear knowledge
		RC-4. Security of radioactive sources: Implementing the Code of Conduct and export/import guidance
	II.2 Developing protection policies, criteria, methods and culture	*RC-9.* Environmental surveillance programmes and dose assessment: Characterization of individual members of the public
		RC-10. ALARA and professional networks: Promoting optimisation of protection through professional networking
		RC-5. Diagnostic reference levels in medical practice
	II.3 Emergency planning, preparedness & response	*RC-13.* Consequence management of malevolent use of radioactive material: Strategies for enhancing security of radioactive materials
		RC-16. Implementation of the international obligations on emergency notification and response

TABLE 2. REFRESHER COURSES (cont.)

Main Fields	Scientific Areas	Refresher Courses (RC)
		Title
III ***Radiation protection and safety in practice***	III.1 Nuclear installations	*RC-17.* Radiation protection in waste management and disposal: Implementing the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management
	III.2 NIRs	*RC-11.* NIR measurements: Principles and practices of EMF characterisation and measurements
	III.3 Medicine	*RC-14.* Radiation protection in paediatric radiology
		RC-18. Shielding of medical facilities: Shielding design considerations for PET-CT facilities
	III.4 NORM in industry	
	III.5 Other applications and practices	*RC-19.* Safe transport of radioactive materials: Security in the transport of radioactive materials
		RC-20. Radiation protection in industrial applications of radioactive sources: Prevention of accidents in gammagraphy
		RC-15. Radon monitoring and control of radon exposure

8. COMMEMORATION

IRPA12 also provided the occasion to celebrate the 80th birthday of the ICRP with an ad hoc conference on the history of the organization, which provides the international radiation protection paradigm. This was done through a keynote lecture by Roger Clarke, former ICRP chairman and currently Member Emeritus. Clarke's paper — co-authored with ICRP Scientific Secretary Jack Valentin — can be found in the Main Field II, "Radiation protection paradigm".

In addition, a ceremony was held in memory of Dr. Dan J. Beninson, the founder of radiation protection in Argentina. Dr. Bo Lindell (Sweden), a leader in radiation protection, addressed the Congress in a film remembering Dr. Beninson.

OPENING SESSION AND SIEVERT LECTURE

WELCOMING ADDRESS

H.E. Ambassador E. Curia
Argentine representative to the
United Nations organizations in Vienna,
Vienna, Austria

Distinguished participants of the 12th Congress of the International Radiation Protection Association, IRPA.

On behalf of the Government of Argentina, it is an honour and a pleasure for me to welcome you most warmly to our country, in my capacity as Governor to the International Atomic Energy Agency and also in my current role as the 2008–2009 President of ARCAL, the Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean.

I would just like to mention that Argentina's bid to host this important Congress was declared to be in the national interest by the president of Argentina in 2004.

From the moment it was decided that Buenos Aires would host this important 12th IRPA Congress, the Government of Argentina, aware of its importance, supported its organization and publicity in all countries and in the international organizations involved in the field of radiation protection.

We also maintained ongoing contacts with a large number of diplomatic missions accredited to Argentina to promote extensive international participation in the Congress.

As a result of these efforts, the Congress has received the co-sponsorship and support of the International Atomic Energy Agency (IAEA), the World Health Organization (WHO) and the Pan American Health Organization (PAHO). These international organizations are also organizing a great many scientific satellite events in connection with IRPA12, which are taking place at various locations around the city of Buenos Aires.

In witness of these efforts and their successful results, it is no surprise that this Congress has attracted over 1500 papers, and we are confident that once everyone has checked in, we will have over 1300 experts and officials here from more than 80 countries. This has made IRPA12, without a doubt, one of the largest international events in this field.

Esteemed participants, in the four years that have passed since the 11th Congress in Madrid, there have been a number of changes in the world that present new challenges to radiation protection.

A few months ago in Vienna, the city where I am stationed, the United Nations Scientific Committee on the Effects of Atomic Radiation completed a new report to be submitted to the United Nations General Assembly.

This report contains details of the global levels and effects of public exposure to radiation caused by new scenarios. I understand that you will receive an extensive report on this new study this morning, but I want to remind you of a few of the new challenges that will need to be faced.

New medical diagnosis and treatment techniques have led to an extraordinary increase in the levels of exposure incurred by patients. Natural radiation, particularly that increased by human activity, has become a matter of serious concern.

In recent years, we have also seen the emergence of a new, almost unthinkable, phenomenon — the issue of security to prevent and mitigate possible terrorist attacks or situations where radiation may be used to spread panic among civil populations.

Finally, we have to be aware that this Congress is set against a backdrop of growing international interest in the renaissance of nuclear energy and its applications.

In line with this current trend, the Government of Argentina has relaunched peaceful nuclear activities and increased cooperation in this field with various countries, particularly our close neighbour, the Federative Republic of Brazil; this cooperation has involved high level presidential meetings and respective joint presidential declarations over the course of this year.

Increasing the benefits of peaceful uses of nuclear energy is a priority of the government, headed by the nation's president.

In this context, Argentina has always ensured that activities involving radiation exposure are carried out in strict compliance with standards for protecting people and their environment. We therefore await your scientific conclusions with great interest.

On another note, I want to remind you that the Government of the French Republic, in collaboration with Argentina's Nuclear Regulatory Authority headed by Dr. Racana, with the help of the government of the Autonomous City of Buenos Aires, has organized an exhibition on the topic of this Congress for the general public at the 'House of Culture' — 10 blocks from here — at 'Plaza de Mayo' square, Avenida de Mayo 575.

This exhibition will be opened the day after tomorrow, on Wednesday, 22 October. This additional effort will undoubtedly help bring your work to the attention of the general public. We are very grateful to the Government of France for its collaboration on this event.

Distinguished participants, I know you have a week of arduous scientific work ahead of you, but I hope that this does not stop you from enjoying the

traditional hospitality of the Argentine people, and that you will have some time for a little tourism, to visit the most beautiful sights of the city of Buenos Aires. To those of you who have more time, I hope you will be able to travel and see the natural beauty found throughout Argentina.

I wish you every success in your discussions — I hope you will be able to produce important conclusions that can be duly taken into account in our work on a permanent basis, and that you have a pleasant stay in our country. Thank you all for being here.

WELCOMING ADDRESS

Dr. R. Racana
President of the Board of Directors,
Nuclear Regulatory Authority of Argentina (ARN),
Buenos Aires, Argentina

Present authorities, esteemed colleagues in radiation protection, ladies and gentlemen.

It is a great honour for me, as president of Argentina's Nuclear Regulatory Authority, which is the competent body for radiation protection and nuclear safety, to welcome you to this extraordinary event.

I say extraordinary because that is the most appropriate adjective to describe this meeting. It is extraordinary because of the large number of participants and their professional quality. Its global representation is extraordinary, with scientists from more than eighty countries. But most of all, it is extraordinary because of the depth of the Congress programme. All topics related to protection against radiation have a place on the programme. In this way we will be able to update ourselves on the latest developments in the fundamental sciences underlying protection, we will also be able to reanalyse the paradigms and models we use in our regulations, and finally, we will ascertain how our efforts have been implemented on a day to day basis.

As you can see, you have a great challenge ahead of you, and I wish you every success.

I would like to finish by thanking you all for being here. It is always difficult to single people out, but I must express special thanks to the following:

— The International Radiation Protection Association, represented here by its president, Dr. Phil Metcalf of South Africa, for choosing Argentina to host this Congress; thank you for putting your trust in us;
— The World Health Organization, represented by one of its Directors, Dr. Maria Neira, the International Atomic Energy Agency, represented by Dr. Eliana Amaral, and the Pan American Health Organization, represented by Dr. Pablo Jiménez, for co-sponsoring the event;
— The Argentine Radiation Protection Society, represented by its president, Ana María Bombén, and all its associates who are present here, for their efforts in organizing the Congress;

— I also want to express special thanks to the Ministry of Foreign Affairs, International Trade and Worship, represented here by His Excellency the Ambassador for Argentina in Vienna, Dr. Eugenio Curia, for providing a great deal of assistance to enable the event to take place;
— In particular, I want to thank President of the Congress, Abel González, and President of the Argentine Radiation Protection Society, Ana María Bombén, for the considerable efforts they have demonstrated in putting on this Congress.

Thank you all — I hope you have a very pleasant stay in Buenos Aires and a very successful Congress.

Thank you very much.

OPENING ADDRESS

A.M. Bomben
President of the Argentine Radiation Protection Society (SAR),
Buenos Aires, Argentina

Dear colleagues from all over the world. Welcome to Argentina. Welcome to Buenos Aires. Welcome to IRPA12.

On behalf of the Argentine Radiation Protection Society (SAR), I would like to share with you the story of a dream that came true. Ten years ago, a few dedicated Argentine scientists tarted dreaming of having an IRPA International Congress in Argentina — the first time in Latin America.

At the IRPA International Congress in Hiroshima, an informal presentation was made, which was only supported by SAR and encouraged by IRPA. There was already a bid for the IRPA International Congress in Madrid, strongly supported by the Argentine Government, through the Minister of Foreign Affairs, the Government of the City of Buenos Aires and national academic institutions. At that moment, many countries supported our proposal, sharing with us our dream.

We worked very hard in these four years, but we were not alone. The strong support of authorities and staff of the Nuclear Regulatory Authority in Argentina was essential in the organization of IRPA12. Around the world, the cooperation of the International Atomic Energy Agency, the Pan-American Health Organization and the World Health Organization was also fundamental for fulfilment our dream.

I would like to mention each of the national and international institutions and colleagues that are supporting IRPA12 with their work, with their funds or with their sponsorship, but there are so many! So, many thanks to all the national and international institutions that are supporting IRPA12; many, many thanks to all the Argentine colleagues and colleagues from all over the world of the different IRPA12 committees, and especially many thanks to all the authorities and colleagues who are here today, with us, sharing this IRPA12 and making real the motto of the Congress: Strengthening Radiation Protection Worldwide.

Many thanks and welcome.

OPENING ADDRESS

E. Amaral
Department of Nuclear Safety and Security,
International Atomic Energy Agency,
Vienna

Good morning ladies and gentlemen.

It gives me great pleasure to represent the IAEA Director General in the opening of the 12th International Congress of the International Radiation Protection Association – IRPA12. This international Congress is a unique and important opportunity for radiation safety professionals to exchange knowledge and share experience on the many aspects of radiation safety.

Let me begin with an acknowledgement and appreciation of the important function that IRPA provides in the support of international cooperation to advance radiation protection worldwide. IRPA makes very effective contributions to human capacity building in radiation safety through networking, expert advice, education and training. Furthermore, IRPA is a key contributor to several important IAEA activities related to radiation protection. These activities include participation in the Radiation Safety Standards Committee (RASSC) and the steering committee on education and training, and reviewing of the revised International Basic Safety Standards for Protection against Ionizing Radiation and the Safety of Radiation Sources (the BSS).

I would also like to thank the Argentine Radiation Protection Society for organizing this important event, bringing together such a diverse group of international experts in the field of radiation safety to reach practical outcomes which can be implemented to advance radiation safety worldwide.

The country of Argentina is an active contributor to international efforts in nuclear and radiation safety, and currently holds the presidency for FORO (Ibero-American Forum of Nuclear and Radiation Safety and Security Regulatory Agencies). FORO has developed, with IAEA support, the Ibero-American Nuclear and Radiation Safety Network. This network serves to promote nuclear and radiation safety and security in the Ibero-American region by providing an effective platform that facilitates knowledge management and technical activities among its participants. I look forward to learning about the results of the various projects under FORO during this conference.

1. PARTNERING TO STRENGTHEN RADIATION SAFETY WORLDWIDE

The motto for IRPA12 is “Strengthening Radiation Protection Worldwide”. This is a goal shared by both the IAEA and IRPA. In this sense, the Agency and IRPA belong to a partnership of cooperation, along with international organizations such as the World Health Organization (WHO), the Pan American Health Organization (PAHO), the International Labour Organization (ILO) and the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), which also share this goal.

To strengthen radiation protection worldwide, continued cooperation between the IAEA and IRPA is essential. Our work, our output and our results provide for continuous improvement of the Global Nuclear Safety Regime that is in place today.

The IAEA leads the international coordination resulting in the availability of high quality safety standards, guidelines, peer reviews and advisory services that support the Global Nuclear Safety Regime. In addition, the IAEA supports the development and implementation of international instruments such as conventions and codes of conduct. Effective use of IAEA standards, guidelines, peer reviews and advisory services, coupled with broad participation in international conventions, will support a stronger Global Nuclear Safety Regime.

International organizations and associations, such as IRPA, are very critical components of the Global Nuclear Safety Regime; they are key actors in the Global Knowledge Network and Global Experts’ Community. IRPA is the world’s largest radiation protection society, with a membership of more than 20 000 radiation safety professionals transcending national boundaries who are united toward a common goal. The combined knowledge and experience of such a large number of experts is a powerful source of support for objective and authoritative assessments of safety, thus promoting high levels of safety. Consequently, IRPA is in a favourable position to help promote the effective use of IAEA safety standards, guidelines, peer reviews and advisory services. IRPA can also assist the IAEA Secretariat in encouraging broader participation in international safety conventions and codes of conduct, in particular the Joint Conventions on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management, and the Code of Conduct on the Safety and Security of Radioactive Sources. Please allow me here to make a reference to the challenge we are now facing regarding safety and security. Safety and security are both essential to the protection of people, society and the environment and — as noted in IAEA Safety Fundamentals document, SF-1 — “Safety measures and security measures must be designed and implemented in an integrated manner”. Our challenge is to achieve this as early and as effectively as possible. In the area

of training and education, IRPA should continue to make its vitally important contributions to ensure that the worldwide nuclear community develops and sustains the necessary human capacity for safety, especially for new countries launching ambitious new nuclear development programmes.

2. FUTURE CHALLENGE AREAS

The international nuclear community, including the radiation protection community, today faces a historical turning point with numerous challenges. There is renewed interest in new nuclear power plants and other advancing nuclear technologies. Some refer to this as the nuclear "renaissance." In this age, we need new thinking and a new approach adapted to dynamically changing global situations. Rather than "renaissance," I prefer to use the phrase "vitae nova" which requires fresh insights, overcoming old mindsets and promoting modest but careful consideration rather than a simple revival of the good old days.

To meet the challenges of the future, members of the broader nuclear safety community, such as IRPA and the IAEA, must achieve closer cooperation. Furthermore, it will become increasingly necessary for those groups with safety interests in specific areas, such as the radiation protection community, to engage more with the broader nuclear safety community.

Please allow me to specifically address three of the numerous challenges we face today — new entrant nuclear programmes, medical exposures and protection of the environment.

2.1. New entrant nuclear programmes

The introduction of nuclear technologies in countries heretofore without nuclear programmes is an issue for the global nuclear community. We are all in the same boat and a serious accident anywhere is a serious problem everywhere. Therefore, it is imperative that new entrant nuclear programmes are launched in a safe and secure manner.

The global nuclear community must do its part to ensure that these new entrant programmes benefit from lessons learned through many decades of experience in the application and regulation of nuclear technologies. The development of a national nuclear safety infrastructure and relevant capacity building are complex undertakings that require inter alia a lifetime commitment to the programme, an effective and independent regulator, a strong safety culture, effective emergency response capabilities and sustainable human capacity.

2.2. Medical exposures

Every day of the year, throughout the world, more than ten million medical radiation procedures are performed. Irrespective of the level of health care in a particular country, medical exposure is consistently the major manmade contribution to the collective dose of radiation to the population, constituting nearly 99% of radiation the public receives from manmade sources.

The IAEA has taken a leading role in informing and training health professionals worldwide through efforts under the International Action Plan on the Radiological Protection of Patients. However, as newer medical imaging and complex radiation therapy techniques are introduced, accidental exposure of patients continues to be reported, and there are new reports of unnecessary and unintended exposures. The Commission on Safety Standards has noted the crucial need to enhance application of the safety standards to reduce the frequency of over or underexposure in nuclear medicine. It is important to meet this evolving challenge with the continuing identification and application of lessons learned and development of safety standards in this area of rapidly growing technological complexity. In this regard, I was very pleased that the IAEA had the opportunity to open yesterday's technical meeting on the radiation safety impact of newer imaging and radiation therapy technologies in medicine.

2.3. Protection of people and the environment

Radiation protection for the environment is an area requiring continued international cooperation to clarify policy and philosophical issues and to develop concrete guidance that can be effectively applied worldwide. The Agency has assisted in the ongoing development of an internationally harmonized system for protection of the public and the environment by coordinating a steering committee on Protection of the Environment, consulting with Member States within the framework of the BSS revision, as well as through ongoing long term collaboration with the ICRP and UN organizations. The safety standards controlling radioactive discharges need to be updated to reflect current best practices and to include essential elements coming from new ICRP recommendations.

Please allow me to address a specific subject relevant to protecting people and the environment. After many years in economic doldrums, the world's uranium industry is experiencing a resurgence of activity. This upsurge in uranium production cycle activities has significant implications for the radiation protection profession. At every stage of the uranium production cycle — from exploration to mining and processing to remediation — there are requirements for appropriate radiation protection procedures and regulations to protect people and the environment. The long period of reduced activity in uranium mining has led

to a shortage of trained and experienced radiation protection professionals associated with the mining industry which will be difficult to overcome. The IAEA is working with radiation protection authorities and uranium mining industry representatives from around the world to address this issue.

3. CONCLUDING REMARKS

In closing, I hope that all participants have a productive and interactive experience at the IRPA international Congress and that these meaningful interactions bring future improvements and developments in safety. The Congress schedule is filled with many important and interesting sessions. I encourage all of you to share your valuable experiences and learn from the experience of others.

OPENING ADDRESS

P. Metcalf
President of the International Radiation Protection Association

Mr Chairman, Dr. Racana, your Excellency Ambassador Curio, President Ana Maria Bomben, Presidents of societies and members of associate societies, distinguished guests, friends and colleagues.

It is a pleasure and an honour for me to welcome you to the 12th international Congress of the International Radiation Protection Association — IRPA12.

On behalf of IRPA I wish to thank the Government of Argentina for welcoming IRPA to Buenos Aires and the Argentinean Radiation Protection Association for offering to host IRPA12 four years ago and for its tireless efforts over the past four years to bring IRPA12 to fruition. It is particularly fitting for IRPA to convene in Buenos Aires, home for many years of one of the icons of radiation protection, the late Dr. Dan Beninson, one of the early council members of IRPA and recipient of the 1996 Sievert award.

IRPA12 — "Strengthening Radiation Protection Worldwide" could not occur at a more relevant time in history. Global concerns over energy supply and climate change have given rise to serious reconsideration of nuclear energy around the world and the re-emergence of the nuclear industry appears inevitable, even through the current economic crisis gives rise to some delay. In addition to the re-emergence of nuclear energy, medical uses of radiation and radioactive materials have accelerated in both volume and complexity at an unprecedented rate.

A considerable number of countries are contemplating the introduction of nuclear energy for the first time, and the shifting world economy is spreading and broadening the use of advanced technologies — including nuclear and radiation related technologies — to many parts of the world. Another dimension of which we are all mindful is current concern over the possible use of radioactive material for malicious purposes and the increasing focus on security of radioactive materials in all forms. In a similar vein, the use of ionizing radiation as a security screening tool gives rise to some difficult questions.

The advent of binding international safety conventions and codes on nuclear, radiation and radioactive waste safety in recent years has led the emergence of a global safety regime calling for high standards of safety to be established, maintained and demonstrated. These developments in turn have created a need for increasing capacities and capabilities in radiation protection. All these developments emphasize the need to strengthen radiation protection

worldwide, and strengthening radiation protection demands consideration of all the dimensions of our profession.

Radiation protection, our profession, is an intriguing blend of science, philosophy, ethics, technology, law and administration. Each is an essential component to achieving and demonstrating the high levels of safety demanded, and each has its own challenges. The IRPA12 programme will enable us to revisit our scientific understanding of these issues, which is certainly not complete but arguably adequate to provide assurance that the increments of radiation exposure associated with the various uses and applications of radiation with which we work do not give rise to undue risks to individuals, society and the environment. We will have the opportunity to debate the underlying philosophies of protection, particularly in the light of new ICRP recommendations, and to hear about advances in technology providing and assuring safety and protection. Sessions are also dedicated to the application of radiation protection in all spheres. The ethical dimensions of our profession will be discussed as will legal and administrative controls applied in assuring safety.

In addition to the scientific programme, a well structure business programme will enable societies and society members to discuss and debate society matters and conduct IRPA business. Included will be discussion on professional competence and recognition, the ethics of radiation protection and the specific issue of stakeholder engagement. We will, however not only discuss the scientific and business dimension of our profession; the Congress provides us with many occasions for social dialogue, to meet colleagues from around the world and exchange ideas and views. The IRPA international Congress is a unique opportunity every four years to gain insight into worldwide developments in all aspects of our profession and to exchange ideas and experience.

Thanks to the tremendous efforts of Abel González, together with the tireless support of his colleagues in the organizing committee and the equally enormous efforts of Eduardo Gallego and the International Congress Programme Committee, we are privileged to look forward to this unique opportunity — the IRPA international Congress, in the vibrant and exciting city of Buenos Aires. We are fortunate to have had invaluable support from the International Atomic Energy Agency in the organization of the Congress which, together with the World Health Organization and the Pan American Health Organization, has also provided support for around one hundred scientists from developing countries around the world to enable them to attend the Congress. Our thanks to Khammar Mrabit for chairing the International Congress Support Committee, which coordinated this tremendous support. As in the past, a number of IRPA associate societies have provided funding, allowing over twenty scientists to attend the meeting, and many societies have supported attendance of their younger members.

The coming week has all the promise of a major step forward in strengthening radiation protection worldwide and I thank once again the Government of Argentina, the Argentinean Radiation Protection Society and the numerous friends and colleagues who have worked toward this moment.

I wish you all a productive and successful Congress and with the ringing of the Polvani Bell, declare the opening of IRPA12.

OPENING ADDRESS

A. Gonzáles
President of the IRPA12 Congress,
Vice-President of the International Radiation Protection Association for Congress Affairs,

Dear colleagues:

We are glad to welcome all of you, arriving from the four corners of the world, to our city Buenos Aires.

Preparatory work for the 12th International Congress of the International Radiation Protection Association (IRPA12) is complete. Great personal efforts and immense professional dedication from many unnamed people has made this possible. The renowned IRPA Congress will take place for the first time in Latin America and will be attended by a massive audience arriving from more than 80 countries around the world. This is the first time in the history of IRPA Congresses that such 'internationalization' is taking place. IRPA12 marks a turning point; IRPA's intentions to globalize the profession are actually being realized and IRPA12's motto, 'strengthening radiation protection worldwide' is coming into effect.

The unremitting work of IRPA12's programme and support committees has led to achievement of their main aims, namely: (i) a renewed scientific programme that will give an exceptional overview of the latest developments in the science and practice of radiation protection, coupled with a novel programme of refresher courses and tutorial seminars that include professional accreditation for the first time, and; (ii) generous support for scientists from developing countries who will have the opportunity to attend an IRPA Congress.

The Argentine Radiation Protection Society (SAR) has fulfilled the IRPA mandate with efficiency in its organization of the Congress. The local IRPA12 organizing committee completed all necessary logistical arrangements to smooth progress for a successful professional meeting. They have cleverly managed available funding and arranged superb facilities in spite of the current volatile international financial situation. The unexpected global monetary turmoil developing at this time threatened the economic feasibility of IRPA12, but for every financial problem a solution was found.

As perfection is an elusive concept, I would like to underline our failures as well, both those which have already occurred and those that might still come. I am the person to be blamed for any shortcomings, for which I am fully, solely and uniquely responsible and humbly apologetic. For instance, it was my intention to

organize a Congress that would fully address both ionizing and non-ionizing radiation with equal emphasis. But I failed to achieve this dream. I thought it would promote wide engagement of the full radiation protection profession from both sides of the energy spectrum. But it could not be. In retrospective, it seems that the 'non-ionizing' community continues to feel less attracted to IRPA than their 'ionizing' counterparts…and this in spite of IRPA's role as generator of 'non-ionizing' internationalization! This situation is certainly unfortunate and detrimental to radiation science.

As promised in the call for papers, both scientists and researchers, as well as regulatory authorities, practitioners and entrepreneurs, will have a place in this event. The proceedings will focus on three major fields as planned: (i) the epistemology of radiation, namely the nature and scope of our knowledge on radiation and its effects and whether acquiring full knowledge is possible (including methods, validity and scope of current knowledge regarding the physical and biological sciences in relation to the effects of radiation exposure); (ii) the paradigm of radiation protection, namely the conceptual model for keeping people safe from health effects due to radiation exposure, and; (iii) the practice of radiation protection, namely application and use of radiation protection plans and methodologies by practitioners and industries making use of radiation.

Several technical sessions addressing topical issues will cover these fields, each featuring a keynote speaker who will summarize the status of the issue, a rapporteur who will summarize contributed papers, some topical presentations of selected papers and an open forum for discussion. Chairpersons of the technical sessions, with the assistance of scientific secretaries provided by SAR, will sum up the various outcomes in concluding plenary sessions. On the first day of the Congress, at a working lunch that will be videoed to the entire Congress, the Argentine regulatory authority will present the local view on radiological security. The next day, at another working lunch, the nuclear power industry will discuss related radiation protection issues. Background plenary sessions will consider the content and direction of current and future work being carried out by relevant international organizations.

Two outstanding scientists will be rewarded for their extraordinary scientific achievements: Dr. Christian Streffer will receive the 2008 Sievert Award and will present the traditional Sievert lecture, and Dr. K. Sankaranarayanan will be awarded the 2008 Gold Medal of the Swedish Academy. IRPA12 is also very privileged to host a jubilee ceremony commemorating the 80th anniversary of the International Commission on Radiological Protection (ICRP) with an *ad hoc* presentation by former ICRP chairman, Professor Roger Clarke.

IRPA12 is pleased to welcome many authorities from national radiation protection societies all over the world. They will be engaged in an active business programme; a natural forum to discuss topics of interest for their societies.

An exhibition on radiation protection for the general public is being organized parallel to IRPA12 by the Government of France. This original initiative is aimed at bridging the gap in understanding that seems to exist between specialists and the general public. I hope that many of you will visit the exhibition, the formal inauguration of which will take place on Wednesday, 22 October at the Buenos Aires 'Casa de la Cultura'.

And last but not least, IRPA12 features a full social programme, which will hopefully make your evenings unforgettable!

Let's fulfil our real promise of four years ago: To make IRPA12 an event to remember with your active participation and support!

I look forward to a successful outcome of IRPA12.

SIEVERT LECTURE

Introduced by
P. Metcalf
President of the International Radiation Protection Association

We come to perhaps the most important and prestigious event of our Congress: the Sievert Award. The Sievert Award honours the memory of Rolf Sievert, one of the founding fathers of radiation protection science and philosophy. And it is my honour, my privilege and my pleasure to introduce Prof. Dr. Christian Streffer, who will present the Sievert Award lecture. Prof. Streffer, a graduate in chemistry and biochemistry, obtained his PhD in molecular radiobiology from the University of Freiburg. Since 1974, he has held various positions at Essen University, including Vice-Chancellor (1988–1992) and Director, Institute of Medical Radiobiology. He has worked for well over forty years in research and application of radiation effects, linking these effects to radiation protection science and practice. His work has been carried out largely at the University of Essen in Germany and at the University of Oxford in the United Kingdom. He has also been very active in the International Commission on Radiological Protection, and first became a member of Committee 1, the radiation effects committee, in 1993. In 2001, he was invited to join the Main Commission of the ICRP and in the period 2001–2007, he chaired Committee 2 of the Commission, dealing with radiation doses from exposure to radiation.

I call upon Prof. Streffer to present the Sievert lecture.

RADIOLOGICAL PROTECTION: CHALLENGES AND FASCINATION OF BIOLOGICAL RESEARCH[a]

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Abstract

In order to evaluate radiation effects in the low dose range (<100 mSv), biological studies are necessary. In this respect, DNA damage and its possible repair as well as adaptive response, bystander effects, genomic instability and genetic disposition of the exposed organism as well as the interplay of these complex processes are of great importance. The implications of such radiation effects on cancer induction — which is a multistep process of mutations and cell cycle regulation — are investigated and discussed with respect to radiological protection.

1. INTRODUCTION

A tremendous amount of data and fascinating insights into life processes have been obtained for biological radiation effects from experimental and clinical investigations as well as from epidemiological studies (Scherer et al. 1991; UNSCEAR 2000; Streffer et al. 2004). This is an important basis for radiological protection. To estimate risk, knowledge of dose responses is decisive. Radiobiological and clinical studies have shown that so called 'deterministic effects' (acute effects, cataracts, malformations) only occur above threshold doses. These threshold doses are above dose limits and reference values used in radiological protection (>100 mSv) (ICRP 2007). In the low dose range (<100 mSv) only genetic and carcinogenic effects are expected. The induction of cancer is the dominating effect. For these latter radiation effects a linear dose response without a threshold (the LNT model) has been proposed, and using this model radiation risk is extrapolated from higher radiation doses to lower doses (ICRP 2007; BEIR 2005). Experimental and epidemiological evidence has been described for such a dose response but it has also been disputed (Tubiana et al. 2005). There is no scientific proof for the LNT model. During recent years biological processes have been studied modulating dose response in the low dose range.

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2. EPIDEMIOLOGY

Very extensive epidemiological studies after exposure to ionising radiation have been performed on cancer involving workers, patients and populations after accidents. In studies on the survivors of the atomic bombs in Hiroshima and Nagasaki, 86 572 survivors with 9335 cancer deaths and 105 427 survivors with 17 448 primary cancer diseases were analysed; both studies came to more or less the same conclusions (Preston et al. 2003; Preston et al. 2007):

- Up to radiation doses of 2 Sv data can be described by the LNT model;
- A statistically significant increase of solid cancers is observed at radiation doses >120 mSv;
- Women are more radiosensitive than men by a factor of about 1:7;
- Children and adolescents are generally more radiosensitive than adults.

These studies are the basis for the risk factor of 5×10^{-2} per Sv for stochastic effects after exposure to low LET radiation in the low dose range with low dose rates and of 10^{-1} per Sv for high LET radiation as derived by ICRP(2007). The data generally show fluctuations around the linear dose response below doses of about 100 mSv. This can be explained by two possibilities:

(1) No cancers are induced after exposure to such low radiation doses.
(2) Cancers are induced after these low doses but the effect is so small that it is hidden by fluctuations in spontaneous cancer rates.

Large fluctuations of the annual cancer rate occur even with large populations. In comparison to these values the expected cancer mortality after radiation doses (low LET, low dose rate) of 100 and 10 mSv is small. It is obvious therefore that the possible radiation effect of doses <100 mSv cannot generally be discovered by epidemiology. An individual cancer which may have been caused by ionising radiation cannot be distinguished from cancers which originate from endogenous or other unknown causes (“spontaneous” cancer or background causes). There is no specific signature existing for radiation-induced cancer. Therefore epidemiology can probably not clarify the connection between cancer induction and radiation in the low dose range. The evaluation of mechanisms may clarify these problems.

3. DNA DAMAGE AND REPAIR

The present view is that the genome of a cell, the DNA, is the primary target for ionising radiation in the production of stochastic effects including cancers. Intensive studies have been undertaken to evaluate DNA damage. The prominent changes after exposure to ionising radiation are:

- Breaks of the polynucleotide strands: single strand (SSB) or double strand breaks (DSB);
- Base damage: either a DNA base is completely lost or radio-chemically altered (UNSCEAR 2000; Streffer et al. 2004).

Analyses of the track structure and distribution of ionisation events in DNA helices revealed that clusters of damage occur after exposure to ionising radiation. Very frequently damaging events occur in the direct neighbourhood of an exposure to an SSB or DSB and form a 'complex SSB' or a 'complex DSB' (Table 1). This DNA damage can be repaired in living cells by different, very sophisticated enzymatic pathways. The complex regulation and efficiency of these processes are dependent on the type of DNA damage. In general, the DNA repair of a DSB is slower and more difficult than that of other damage types and this is especially the case for complex DSB. With DSB misrepair can also occur. Misrepaired DSB may be involved in the initial steps for cancer development.

These mechanisms are still not fully understood. In earlier times, the dogma was that any damage to DNA is an irreversible process leading either to a mutation or cell death. Today it is well known and proven that DNA is a labile molecule and stability of the genome can be maintained throughout life only through DNA repair. The occurrence of clustered DNA damage is unique to ionising radiation (Goodhead 2006; UNSCEAR 2000). Chemical toxic agents

TABLE 1. DNA DAMAGE AFTER EXPOSURE TO IONIZING RADIATION (PERC.)

DNA Damage (Perc.)	100 keV Electr.	2 MeV Alpha-Part.
Base Damage	81.8	53.3
SSB	16.9	23.1
Compl. SSB	0.71	8.7
DSB	0.47	4.01
Compl. DSB	0.12	11.0

generally cannot generate such clustered complex DNA damage in the low dose range. The damaging events of such agents are usually isolated. Further the quantitative distribution of various damage types is dependent on the radiation quality. Low LET radiation induces less DSB and especially less complex DSB than high LET radiation (Table 1). This is one of the reasons for the observation that DNA damage from high LET radiation is repaired less efficiently than that from low LET radiation and therefore high LET radiation leads to higher RBE than low LET radiation (Streffer et al. 2004).

In all living mammalian cells DNA is associated with proteins — mainly histones — in order to form chromatin. After radiation exposure, the histone H2AX becomes phosphorylated in the area of DNA damage. Using an immunofluorescence technique, DSBs can be counted in a very sensitive manner. DSBs can be observed after low LET radiation doses of several mSv (Loebrich and Kiefer 2006). DNA repair is dependent on genetic disposition; the radiosensitivity of individuals differs widely due to this. With respect to their radiosensitivity, most humans fall into a certain range within a Gaussian distribution. However, some individuals have been observed to have high cellular radiosensitivity, showing a strong repair deficiency (e.g. Ataxia Telangiectasia (AT) patients) (ICRP 1998; Müller et al. 2001; Streffer et al. 2004). With these individuals all deleterious radiation effects are enhanced.

4. DOSE MODIFYING PHENOMENA

Several biological phenomena can modulate dose response in the low dose range and may modify the dose response curve in various ways in the low dose range (<100 mSv) (Figure 1). Very important phenomena include DNA repair processes which have already been discussed. Further adaptive response, apoptosis, bystander effects, genetic disposition, genomic instability, hyperradiosensitivity and immune response have to be mentioned. Some of these phenomena will be discussed.

Adaptive response has been frequently observed during the last 20 years (UNSCEAR 1994; Streffer 2004). In general, biological objects, usually cells like bacteria or human lymphocytes, are irradiated with a low dose (adapting the dose in a range of 5 to 200 mGy). About 4 to 24 hours later a higher dose (a challenging dose in the range of 1 to several Gy) is given and the biological effects (usually chromosome aberrations with lymphocytes) are measured. In parallel the effect of the challenging dose alone is measured. Quite often the radiation effect is reduced with the combination of adapting dose plus challenging dose in comparison to the effect of the challenging dose alone. The cells become more resistant to ionising radiation after the small dose; they adapt.

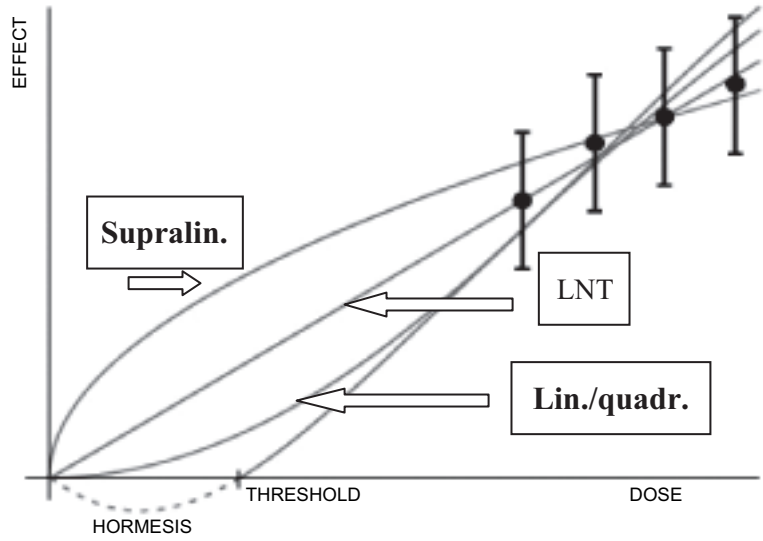

FIG. 1. Possibilities for the extrapolation of stochastic radiation effects.

Apparently DNA repair becomes more efficient through adaptation (UNSCEAR 1994; Streffer 2004). Such effects have been shown in many cases throughout all of living nature with prokaryotic as well as eukaryotic organisms.

However, the effect can be very different between individuals. The adaptive response is apparently dependent on genetic disposition. No adaptive response was observed in cells from individuals with radiosensitive syndromes like Ataxia Telangiectasia (AT). Several studies have shown no or very little adaptive response developed with high LET radiation. Usually experiments in adaptive response have been performed with low LET radiation. During prenatal development no or little adaptive response is also observed; further it has been found that adaptive response seems to decrease with age. One must also consider that very well defined conditions with respect to the size of the adapting dose and dose rate, the time interval between adapting and challenging dose and other parameters have to be maintained (Streffer 2004). Thus, it can be concluded that adaptive response is a very important biological phenomenon of high scientific interest. However, it has a number of limitations, it is not an universal phenomenon.

Apoptosis is a very powerful cellular mechanism which eliminates damaged cells or those no longer needed, for example during prenatal development it is triggered by intracellular processes. It can increase after radiation exposure and it is assumed that apoptosis may also eliminate malignant

cells so that cancer risk is reduced. It has further been shown that small radiation doses can induce an adaptation with increased apoptotic activities but again this differs very much between individuals (Streffer 2004). Apoptotic cell death is induced by complex intracellular signal transduction mechanisms which are triggered and regulated by a number of molecular factors (such as the tumour suppressor p53) which are also sometimes connected to the cycle of cell proliferation. At these branching points the cell can decide to undergo apoptotic cell death or proliferation. In many cancers the tumour suppressor p53 or other regulating factors are inactivated by mutation or other translational processes. In these cells apoptosis is reduced and thus the mechanism of cell elimination by apoptosis does not work (Oya et al. 2003; BEIR VII 2005).

For a long time it was accepted that radiation induced chromosomal damage is expressed in the first mitosis taking place after radiation exposure. Nowadays it is well known, however, that this is not the always the case. In the first mitotic cell divisions, cells proliferate quite normally; new chromosomal aberrations can appear in later mitotic cell divisions. For example, female mice were irradiated briefly after conception (about 1–3 hours) when the conceptus was still in the zygote (1-cell) stage. The embryo/foetus developed into normal mice in utero, but an increased number of chromosomal aberrations were measured in fibroblasts of the foetuses just before birth. This means that a normal foetus developed from the irradiated zygote, but that some latent radiation damage was expressed in cells many cell generations later around the time of birth. The cells had developed an increased 'instability of the genome' (Pampfer and Streffer 1989). Such effects have been found in many cell systems and organisms (in vivo and in vitro) during the last 20 years (UNSCEAR 2000; BEIR VII 2005; Lorimore et al. 2003; Kadhim et al. 2006; Huang et al. 2007).

Besides cytogenetic effects, genome instability has also been observed for a number of other biological endpoints. It can also be transmitted to the next generation of mice. Genome instability develops after high and low LET radiation (Kadhim et al. 2006). Dose response is not quite clear; the lowest radiation doses significantly increasing genomic instability are usually in the range of several hundred mGy X rays (Streffer et al. 2004). However, Okada et al. (2007) observed an increase in DSBs measured using the immunofluorescence-γ-H2AX method more than 20 cell generations after radiation exposure to 1 mGy of carbon ions. This is the radiation dose averaged over all cells, however, only one in 18 cells is exposed under these conditions. Thus the dose in the exposed cell is around a factor of twenty higher. Nevertheless these data show that small doses can possibly induce genomic instability.

Extensive experimental studies have been performed in recent years on so-called bystander effects. Thus it has been observed in cell cultures with single cell irradiation that not only the exposed cells show a response but also unexposed

neighbouring cells (Morgan 2003). These bystander effects have been mainly studied with cells in vitro. They may lead to an enhancement of radiation effects in vivo. However, protective effects have also been discussed in this connection. Nevertheless, all these phenomena can have the ability to modify dose response in the low dose range (Figure 1). How this can happen is still unclear. It should further be stated that in the development of these radiation effects, epigenetic effects are involved, although the mechanisms for bystander effects and for the increase in genomic instability are not clear at all.

5. MECHANISM OF CARCINOGENESIS AND ASSOCIATION WITH GENOMIC INSTABILITY

The present concept about the mechanism of cancer development is roughly the following: initial events change/damage DNA, which may be repaired or the damaged cell starts to proliferate with either unrepaired or misrepaired DNA. The daughter cells then carry a mutation. Probably further proliferation leads to cell transformation, and malignant cells are formed. These cells may stay latent for many years, they can disappear by apoptosis or through immune response, but further mutations may alter the regulation of cell proliferation and stimulate these processes to result in pre-cancer stages. After further cell proliferation and mutations a carcinoma in situ is formed which can develop into cancer with metastases. In summary, the development of cancer mainly occurs after several successive mutations and extensive cell proliferation. It is assumed that cancer develops from one malignant cell and a clinically diagnosed cancer has around one billion cells (Cancer Medicine 2005). The latency period (time for development of a cancer) is in the range of 5 to 10 years for most leukaemia and for most solid cancers in the range of decades after radiation exposure (Streffer et al. 2004).

In some tissues or organ systems (bone marrow, epithelia, skin) cell proliferation is very intensive; around 600 billion cells are formed in an adult per day. Nature has to be very efficient and has several mechanisms in place in order to avoid mistakes. Checkpoints exist in cycle cell proliferation before the cell starts DNA synthesis (S) or mitosis (M). In the case of damaged DNA, further migration through the cycle can be stopped (G_1- or G_2-block) for a certain time (hours) at these checkpoints and the cell tries to repair damage before it continues in the cycle. During the development of cancer, changes in or complete disruption of regulatory processes occurs. One feature of cancers is that cell proliferation never stops. In normal tissues and organs cell proliferation comes into a steady state equilibrium in which the renewal of cells is in agreement with the loss of cells. This is not the case for cancers. Further it is well known that cancer cells

have increased genomic instability (Cancer Medicine 2005; Streffer 2000). However, it is interesting that the increased genomic instability is apparently not limited to the cancer cells but also occurs in normal cells such as peripheral lymphocytes of a cancer patient. Thus increased genomic instability was observed in lymphocytes of uranium miners who experienced radiation exposures as workers in mines decades earlier and had developed lung cancer (Kryscio et al 2001).

As earlier explained, several syndromes with specific genetic predisposition for high radiosensitivity exist, including: Ataxia Telangiectasia, Bloom´s Syndrome, Fanconi Anemia, Li Fraumeni Syndrome, Neurofibromatosis and Retinoblastoma (ICRP 1998). All individuals with these syndromes show proneness for cancer, reduced DNA repair and increased genomic instability. These data demonstrate strong evidence for a causal association between genomic instability and cancer. The length of telomeres may be important for genomic instability. Telomeres are nucleotide sequences which terminate and stabilize chromosomes. Studies on patients treated with radiation for the malignant disease M. Hodgkin showed a reduction in the length of telomeres in comparison to unirradiated control persons. The reduction was most significant in patients who developed a secondary cancer after treatment. In a group of patients who were followed after treatment, two patients developed a secondary cancer and again the telomeres were especially shortened in these patients, who also had measurable chromosome aberrations in their lymphocytes. A strong association between an increase of genomic instability and reduction of telomeres was observed (M´Karcher et al. 2007).

6. CONCLUSIONS

Radiobiological research has resulted in the discovery of some fundamental general biological phenomena, for example: induction of mutagenesis by an exogenous agent, discovery of DNA repair processes, discovery of the cell cycle for cell proliferation, induction of increased genomic instability through a toxic agent. This research has made strong contributions to radiological protection.

Epidemiological studies are important in order to evaluate quantitative risk factors for cancer after radiation exposure, however they will not solve the open question of risk in the low dose range (<100 mSv). Biological studies show effects (such as DSB and chromosome aberrations) with dose ranges as low as several to 50 mSv, which is lower than with epidemiology. These studies support the view that no threshold exists for certain effects like mutations. Observations of radiation effects <1 mSv appear to be impossible due to background effects by endogenous processes and radiation effects from natural sources. Genomic

instability is associated with the development of cancer. It is increased in all individuals who have high radiosensitivity. Studies of biological processes may lead to a modification of the LNT model. Unfortunately biological radiation effects, especially late effects like cancer, cannot be discerned from 'spontaneous' effects.

Radiation induced cancer is dependent on many factors. It differs from organ to organ. The dose response is different for various cancer entities etc. For a uniform system in the low dose range (both sexes, all ages, all sensitivities, all radiation qualities) LNT with reference values appears to be the only way to go for prospective radiological protection. The LNT risk model is also used for risk estimates after exposure to genotoxic substances.

However, for individual risk evaluation individual factors (sex, age, exposure conditions, possible genetic predisposition) have to be used. The LNT model in connection with effective dose should not be used for this purpose. In the low dose range the uncertainties of dose estimates and risk evaluation are high. Radiation exposures from natural sources and other background risks interfere with risk evaluation. Collective dose — usually based on low individual doses — is not useful for risk evaluation. It is a useful tool for optimisation in radiological protection.

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MAIN FIELD 1:
EPISTEMOLOGICAL BASIS OF RADIATION PROTECTION

BACKGROUND PLENARY SESSION I

LEVELS AND EFFECTS OF IONIZING RADIATION: THE LATEST UNSCEAR REPORTS

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Abstract

This paper aims to summarize the latest findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) with respect to levels and effects of ionizing radiation exposure. The annual average worldwide exposure is now 3.0 mSv; ~80% of which is due to natural sources of radiation, ~20% due to medical exposure, <0.2% due to weapons fallout, <0.1% due to the Chernobyl release and < 0.01% due to nuclear power. Individual doses depend primarily on exposure to radon, medical treatment history, occupational exposure and proximity to test or accident sites. In some countries medical exposure now exceed exposure from natural sources. The committee has recently completed detailed assessments of: the latest epidemiological evidence for radiation induced cancer and non-cancer diseases; non-targeted effects; effects on the immune system; effects on non-human biota; and effects of exposure to radon — recent pooled studies support a small but detectable increased lung cancer risk from residential exposure. While differences exist at the detail level, the overall risk factors for radiation exposure remain essentially unchanged.

1. INTRODUCTION

This paper summarizes the latest findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) with respect to levels and effects of ionizing radiation exposure.

2. BACKGROUND

UNSCEAR was established by resolution 913 (X) of the United Nations General Assembly on 3 December 1955. Its mandate is to undertake broad reviews of the sources of ionizing radiation and of the effects of that radiation on human health and the environment. In pursuit of its mandate, the committee thoroughly reviews and evaluates global and regional exposure to radiation and

evaluates evidence of radiation induced health effects in exposed groups, including survivors of the atomic bombings in Japan. The committee also reviews advances in understanding of the biological mechanisms by which radiation induced effects on health or on the environment can occur. Those assessments provide the scientific foundation used, inter alia, by the International Commission on Radiological Protection (ICRP) in developing its recommendations on radiation protection and by the relevant agencies of the United Nations system in formulating international standards for protection of the public and of workers against ionizing radiation[1]; those standards, in turn, are linked to important legal and regulatory instruments.

The committee reports progress annually to the General Assembly and every few years the United Nations publishes substantive findings of the committee. The most recent substantive reports were made to the General Assembly in the years 2006 and 2008 respectively [1, 2]. All UNSCEAR published reports are available for download at www.unscear.org.

3. SOURCES AND LEVELS OF IONIZING RADIATION

3.1. Natural sources

The main natural sources of exposure to ionizing radiation are cosmic rays and terrestrial radionuclides. Exposure are external and internal (due to inhalation and ingestion) and constitute a global annual average per caput dose of 2.4 mSv, with typical individual annual doses ranging from about 1 to 13 mSv (see Table 1).

This large range is mainly due to inhalation of radon decay products, which gives rise to a global average per caput dose of 1.3 mSv; the typical range of individual annual doses is about 0.2 to 10 mSv. While the exposure of most people around the world is close to the global average annual dose of 2.4 mSv, many people in many areas receive annual doses in the order of 10 mSv; a few people in a few areas receive annual doses of 100 mSv.

[1] FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS, INTERNATIONAL ATOMIC ENERGY AGENCY, INTERNATIONAL LABOUR ORGANIZATION, OECD NUCLEAR ENERGY AGENCY, PAN AMERICAN HEALTH ORGANIZATION, WORLD HEALTH ORGANIZATION, International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, Safety Series No. 115, IAEA, Vienna (1996).

TABLE 1. ANNUAL PER CAPUT DOSES AND RANGES OF INDIVIDUAL DOSES FROM NATURAL SOURCES OF RADIATION

Source or mode	Global annual average per caput dose (mSv)	Typical range of individual annual doses (mSv)	Remarks
External exposure			
Cosmic radiation	0.4	0.3–1	The dose increases with altitude.
External terrestrial	0.5	0.3–1	The dose is higher in some locations.
Internal exposure			
Inhalation (radon gas)	1.3	0.2–10	The dose is much higher in some dwellings.
Ingestion	0.3	0.2–1	
Total natural	**2.4**	**1–13**	**Sizeable population groups receive 10-20 mSv**

3.2. Medical exposure

With regard to artificial sources of radiation, medical exposure remains by far the largest, continuing to grow at a remarkable rate. Irrespective of the level of health care in a country, medical uses of radiation continue to increase as techniques develop and become more widely disseminated. In some countries medical exposure now exceed exposure from natural sources. Between the period 1991–1996 and 1997–2007, the annual number of diagnostic medical examinations (including dental examinations) is estimated to have risen from 2.4 billion to 3.6 billion globally — an increase of approximately 50%. However, care is needed in interpretation. Medical exposure by a patient is almost always voluntary and provides a direct benefit to the exposed individual. Moreover, patients may be sick or older than the general population. Direct comparison of doses with other sources may be inappropriate.

Access to medical care differs significantly between countries, and is reflected in different annual medical exposure. For example, medical X ray examinations are over 65 times more common per person in countries with high levels of health care (accounting for 24% of the world's population) than in countries with the lowest levels of health care (accounting for 27% of the population). The wide imbalance in health care provision is also reflected in the availability of X ray equipment and physicians.

Between the 1993 and 2008, UNSCEAR surveys uncovered evidence that the annual per caput dose from diagnostic radiology increased from 0.3 mSv to 0.6 mSv. As part of this trend, new, high dose X ray technology, particularly computed tomography (CT) scanning is leading to extremely rapid growth in the annual number of procedures performed in many countries and, by extension, a marked increase in collective doses. In the United States, for example, CT frequency during the last 15 years grew about 10% per year, while in comparison the size of the US population increased only 1% per year. Moreover, studies have shown an order of magnitude spread in CT scan doses for ostensibly the same examination, indicating a large potential for optimizing protection. By comparison, population exposure due to nuclear medicine are much smaller and are not growing so rapidly.

The increased use of digital radiology also has new associated risks. In digital radiology, underexposed procedures cannot be corrected, but overexposure can be readily corrected by simply adjusting computer parameters; thus there is a potential bias for increased doses to patients. Because of the relatively higher risks for neonates, attention should be given to the delivery of any doses to them. It is often the case that the whole body of neonates is exposed as opposed to the radiation being focussed precisely on a specific target area. The occurrence of unintended medical exposure such as radiotherapy accidents and injuries resulting from intervention procedures is considered below.

3.3. Military activities

Nuclear test explosions in the atmosphere were conducted at a number of sites, mostly in the northern hemisphere, between 1945 and 1980, with the most active testing taking place between 1952–1958 and 1961–1962. In all, 502 tests were conducted, with a total yield of 434 megatonnes of TNT equivalent. The injection of radioactive material into the atmosphere represents the largest radioactive releases into the environment. The associated estimated annual per caput effective dose reached a peak in 1963 at 0.11 mSv, and subsequently fell to its present level of about 0.005 mSv (see Figure 1). This source of exposure will decline very slowly in the future because most of the radiation is now due to globally circulating carbon-14 (half-life, 5730 years). Global exposure from the more than 1800 underground tests were negligible by comparison.

People living near test sites were also exposed to local fallout. Because the sites and characteristics of the tests differed substantially, doses could only be estimated separately after detailed studies were undertaken at each site. Many such studies were carried out in the late 1990s and early years of the present decade and are still continuing. It is clear that some people living near some of the sites at the time of testing received very large doses (e.g. thousands of

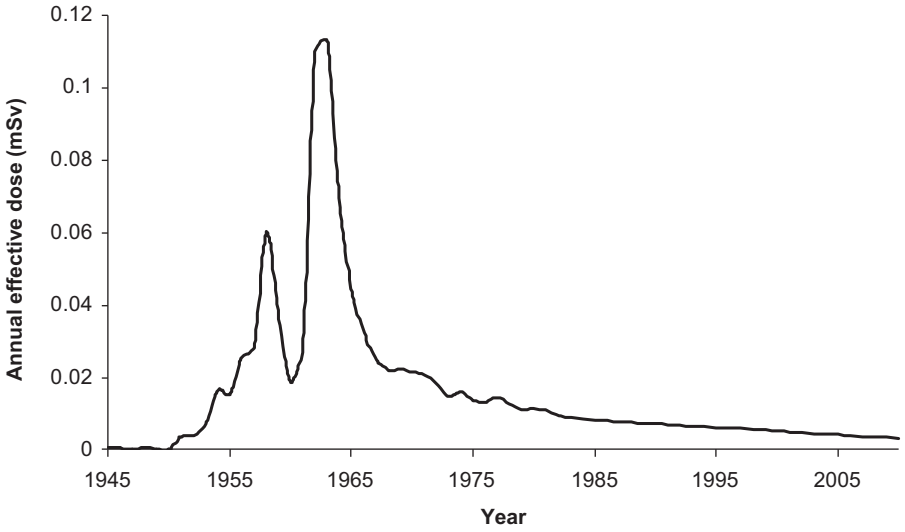

FIG. 1. Estimated annual per caput effective dose worldwide from atomic bomb tests, 1945–2005.

millisieverts at the Semipalatinsk nuclear test site). Because radioactive residues at some of these sites may be considerable, there is concern about returning the sites to civilian use.

In addition to testing, discharges from installations where nuclear materials were produced and nuclear weapons manufactured were often not controlled sufficiently and represent another source of environmental release that exposed local populations (e.g. at the Hanford plant and at Chelyabinsk). Military use of depleted uranium, especially in armour piercing munitions, has raised concerns about residual contamination; however chemical toxicity is the more significant hazard and — except for a few specific scenarios (such as long term handling) — radiation exposure is generally negligible.

3.4. Civil nuclear power

The generation of electrical energy by nuclear power plants has grown steadily since the industry began in 1956. Despite increases in the decommissioning of older reactors, electrical energy production from nuclear sources continues to grow (see Figure 2). As of 2007, some 439 nuclear power reactors in 31 countries provide approximately 15% of the world's electricity.

Overall, an annual collective dose of about 200 man Sv is estimated for all operations related to electrical energy production.

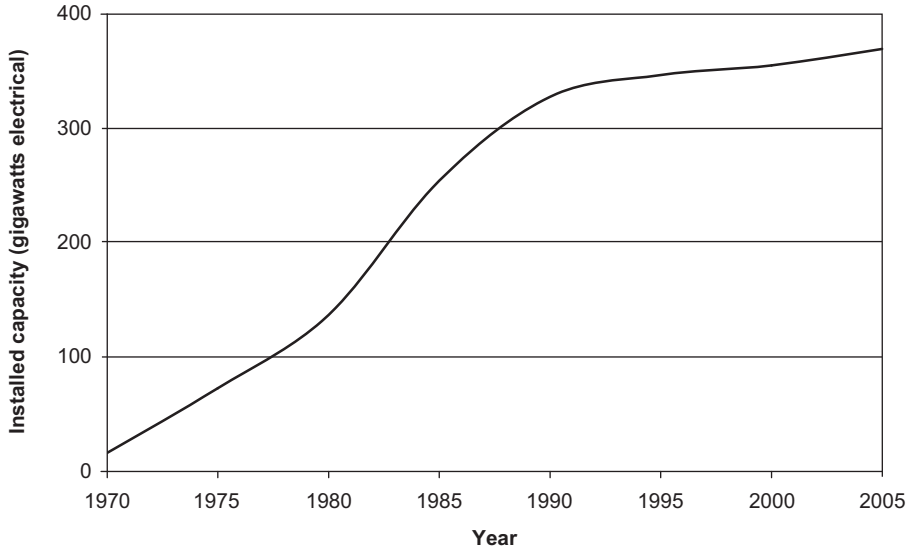

FIG. 2. Installed nuclear electricity generating capacity worldwide, 1970–2005.

The dominant component of those operations is mining (uranium mining and milling produces substantial quantities of residue in the form of tailings; up until 2003, the total world production of uranium was about 2 million tonnes, and the resultant tailings totalled over 2 billion tonnes). The annual per caput dose to representative local and regional populations around nuclear power plants is less than 0.0001 mSv, but up to 0.02 mSv for critical groups 1 km from some reactor sites. The global average dose due to the nuclear fuel cycle is about 0.0002 mSv primarily from globally dispersed long-lived radionuclides released during reprocessing and operations.

3.5. Occupational exposure

The total number of workers exposed to ionizing radiation is currently estimated to be about 22.8 million, of whom about 13 million are exposed to natural sources of radiation and about 9.8 million to artificial sources. The mining sector accounts for the vast majority of occupationally exposed workers, and radon is the main source of exposure in underground mines of all types. Medical workers comprise the largest proportion (75%) of workers exposed to artificial sources. Figure 3 summarizes exposure for various major work categories, indicating the importance of enhanced exposure to natural radiation. While the average dose to workers exposed to artificial sources of radiation has fallen

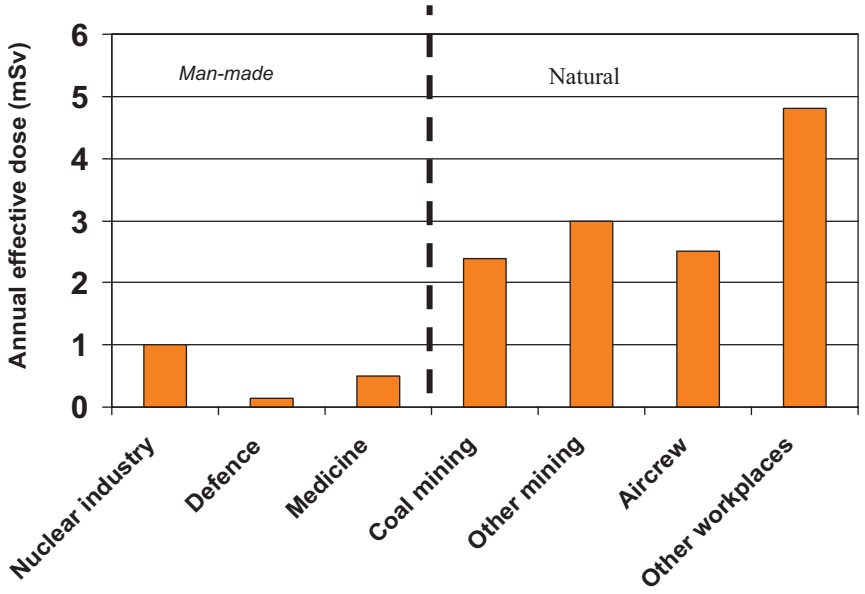

FIG. 3. Illustrative average annual doses for various occupations.

substantially over the past two decades, occupational exposure from natural sources has changed little.

While electrical energy generated by nuclear means has increased about fourfold between 1975 and 2005 (Figure 2), the average annual dose to monitored workers in the nuclear fuel cycle has fallen from 4.4 mSv in 1975 to 1.0 mSv at present. The total occupational exposure at commercial power plants divided by the energy produced has also fallen steadily over the past three decades (Figure 4).

3.6. Accidental exposure

A small number of accidents associated with the nuclear fuel cycle have occurred and have attracted widespread publicity. However, more than 100 accidents have occurred with industrial and medical sources, especially with 'orphan sources', and those accidents have caused early acute effects in workers and members of the public. Accidents have also occurred in radiation medicine involving human or machine error. Accidents involving orphan sources and those related to radiation medicine have become more frequent, but the data seems to suffer from underreporting. Nevertheless, reported accidents in medical use alone show that more people have been injured in this category than in any other.

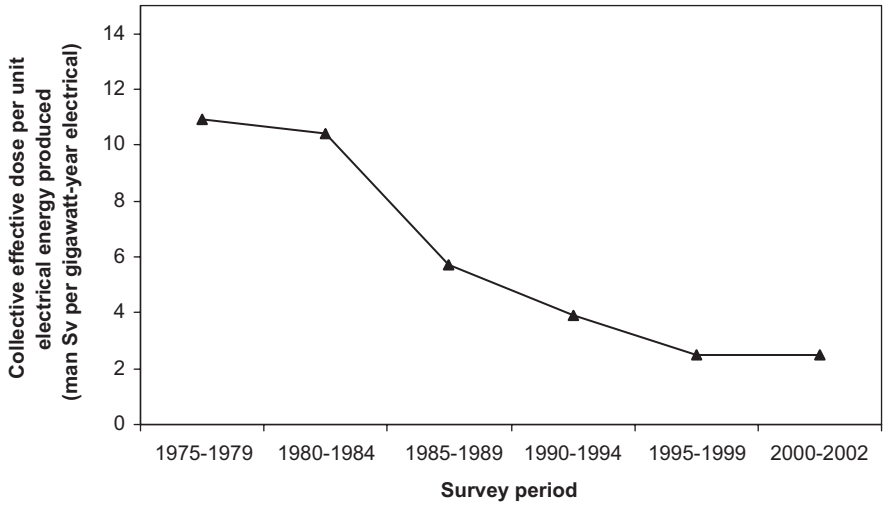

FIG. 4. Annual occupational collective dose at reactors, normalized to unit electrical energy produced.

Table 2 illustrates estimates of collective doses from accidents which exposed the general public to radiation. The collective dose from the Chernobyl accident was many times greater than the combined collective dose from all others, and yet only a small fraction of the collective dose released due to atmospheric weapons testing.

The collective dose from atmospheric weapons testing was 22 million man Sv.

3.7. Chernobyl accident

In 1986, an accident at Chernobyl took place; it was the most severe accident in the history of civilian nuclear power. Two workers died in the immediate aftermath, and 134 plant staff and emergency personnel suffered acute radiation syndrome, which proved fatal for 28 of them. Skin injuries and radiation induced cataracts were among the main sequelae of the survivors. Nineteen have died since; however the causes of their deaths had causes were usually not associated with radiation exposure. Several hundred thousand workers were subsequently involved in recovery operations. Among those exposed to the highest radiation doses in 1986 and 1987, there are some reports of increased incidence of leukaemia and cataracts; there is no other consistent evidence to date of other longer term radiation related health effects. Among the general public, children or adolescents in 1986 in affected areas of the former Soviet Union

TABLE 2. ILLUSTRATIVE COMPARISON OF COLLECTIVE DOSES FROM ACCIDENTS EXPOSING THE GENERAL PUBLIC

Year	Accident	Collective dose (man Sv)
1986	**Chernobyl**	**295 000**
1957	Kyshtym	2 500
1964	SNAP 9A	2 100
1957	Windscale fire	2 000
1983	Ciudad Juarez	150
1987	Goiânia	60
1979	TMI	40
1978	Cosmos 954	20
1966	Palomares	3
1999	Tokai-mura	<0.6
1993	Tomsk	0.02

suffered repercussions; more than 6 000 cases of thyroid cancer have been reported (up to 2005, only 15 cases had proven fatal), of which a substantial portion could be attributed to drinking milk contaminated with iodine-131. The 20-year average effective dose to the general population in contaminated areas is 9 mSv, ranging up to a few hundred millisieverts in some places. In the longer term, there has been no consistent evidence yet of any other radiation related health effects among the general population. The committee has decided not to use models to project absolute numbers regarding effects in populations exposed to low doses because of unacceptable uncertainties in predictions. Based on 20 years of studies, it is possible to essentially reconfirm the conclusions of the UNSCEAR 2000 Report.

3.8. Summary of levels

The annual average worldwide exposure to radiation is 3.0 mSv, ~80% of which is due to natural sources of radiation, ~20% to medical exposure, <0.2% to weapons fallout, <0.1% to the Chernobyl release and < 0.01% to nuclear power. Individual doses depend primarily on exposure to radon, medical treatment history, occupational exposure and proximity to test or accident sites (see Table 3).

TABLE 3. ANNUAL AVERAGE DOSES AND RANGES OF INDIVIDUAL DOSES BY SOURCE

Source or mode	Annual average dose (worldwide)	Typical range of individual doses	Comments
Natural sources of exposure (Table 1)	2.4	1–13	Sizeable population groups receive 10–20 millisieverts (mSv).
Artificial sources of exposure			
Medical diagnosis (not therapy)	0.6	0–several tens	The averages for different levels of health care range from 0.03 to 2.0 mSv; averages for some countries are higher than that due to natural sources; individual doses depend on specific examinations.
Atmospheric nuclear testing	0.005	Some higher doses around test sites still occur.	The average has fallen from a peak of 0.11 mSv in 1963.
Occupational exposure	0.005	~0–20	The average dose to all workers is 0.7 mSv. Most of the average dose and most high exposure doses are due to natural radiation (specifically radon in mines).
Chernobyl accident	0.002[a]	In 1986, the average dose to more than 300 000 recovery workers was nearly 150 mSv; and more than 350 000 other individuals received doses greater than 10 mSv.	The average in the northern hemisphere has decreased from a maximum of 0.04 mSv in 1986. Thyroid doses were much higher.
Nuclear fuel cycle (public exposure)	0.0002[a]	Doses are up to 0.02 mSv for critical groups at 1 km from some nuclear reactor sites.	
Total artificial	**0.6**	**From essentially zero to several tens**	**Individual doses depend on medical treatment, occupational exposure and proximity to test or accident sites.**
TOTAL EXPOSURE	**3.0**	**From essentially one to several tens**	**Individual doses depend primarily on exposure to radon, medical treatment, occupational exposure and proximity to test or accident sites.**

[a] Globally dispersed radionuclides.

4. EFFECTS OF EXPOSURE TO IONIZING RADIATION

UNSCEAR synthesizes knowledge on the effects of exposure to ionizing radiation, not through reliance on single research papers, but through the systematic review of all relevant published material in the field of interest, including results of clinical research, epidemiological studies, animal experiments, and cellular and molecular biology investigations.

4.1. Recapitulation

The basic premise of radiation response is that any radiation interaction with DNA results in damage that if not repaired or if incorrectly repaired may represent an initiating event in tumourigenesis or lead to cell death. If doses are sufficiently high to cause many cells in a tissue to die, then general tissue effects may be seen (deterministic effects). If the cell survives but the DNA has been mutated, then the cell may be a viable cell with carcinogenes. If the immune system does not function properly, tumourigenesis may be promoted, leading years later to malignant conversion and ultimately metastasis of the malignancy. If the mutated cell is a germ cell, then heritable effects may be transmitted to offspring.

4.2. Cancer epidemiology

The committee has always relied heavily upon results of epidemiological studies in estimating the risks of radiation induced cancer. It has highlighted criteria defining good quality epidemiological studies. The statistical power of a study is greatly affected by sample size, dose level of the exposed group and magnitude of the risk coefficient, such that most low dose studies reported in literature have inadequate statistical power.

The committee has reviewed many epidemiological studies (e.g. of radium dial painters, the population at the Semipalatinsk test site, Mayak workers, atomic bomb survivors, medically and occupationally exposed groups, and many others). The survivors of the bombings at Hiroshima and Nagasaki (Life Span Study) included 86 611 individuals of both sexes and all ages, with a wide dose range (average dose 0.1 Gy, maximum 4 Gy). The total number of deaths from solid cancer was 10 127, of which 479 were attributable to radiation exposure, including 296 deaths from leukaemia (93 attributable to radiation exposure).

Specific cancers considered by UNSCEAR in its 2000 report were extended in the 2006 report to include those of the salivary glands, small intestine, rectum, pancreas, uterus, ovary, and kidney, as well as cutaneous melanoma. Results of the committee's analysis show the sensitivity of estimates of lifetime cancer risk

due to radiation exposure to variations in background rates of spontaneous cancers. Findings suggest that this variability can lead to differences comparable to those associated with different methods of transferring risk estimates between populations or methods of risk projection. Despite these difficulties, risk estimates are of considerable value in characterizing the impact of radiation exposure on a population. The lifetime risk of death following an acute dose of 1 Sv is estimated as an average over five specific populations to be about 4.3 – 7.2% and 0.6 – 1% for all solid cancers together and leukaemia respectively. For an acute dose of 0.1 Sv the risk estimates are 0.36 – 0.77% and 0.03 – 0.05% for solid cancers and leukaemia respectively. The present estimate of risk for solid cancer following 1 Sv is slightly lower than the previous UNSCEAR estimate. The reduction may be due to new atomic bomb dosimetry and follow-up, although it is probably in larger part due to different risk projection and transport models used. Lifetime risk estimates for children could be higher by a factor of 2 to 3 times than for a mixed age group. Regarding hereditable effects, the total risk to the first generation from parental exposure is unchanged from the UNSCEAR 2000 report estimate of 0.0002%/mSv; however no direct evidence for such effects has ever been seen in exposed human populations.

4.3. Non-targeted effects

A basic paradigm of radiobiology is that detrimental irradiation effects have their origin in irradiated cells or, in the case of heritable effects, in cells directly descended from them. However the UNSCEAR 2006 report completed a substantive review of so-called non-targeted and delayed effects which challenge this view. They include the phenomena of:

(a) genomic instability: if a single cell is irradiated and survives, it may produce daughter cells that over generations have increasing numbers of alterations in their genomes, even thought the daughter cells themselves were not irradiated;
(b) bystander effects: the ability of irradiated cells to convey manifestations of damage to neighbouring cells which have not been irradiated;
(c) abscopal effects: a significant response in a tissue that is physically separate from the region of the body irradiated;
(d) clastogenic plasma effects: blood plasma from irradiated animals is capable of inducing chromosomal damage in unexposed cells after transfusion.

The committee concluded that there may be associations with disease, but as yet no evidence of causation. It stressed that the estimation of radiation induced health effects is based on epidemiological and experimental observa-

tions, including a statistically significant dose related increase in disease incidence. Mechanistic information is important for judgements on health effects below about 0.2 Gy. The committee recommended that future research studies should emphasize reproducibility, low dose responses and causal associations.

4.4. Immune system effects

The immune system is one of the most complex systems of the human body, and protects against infections and cancer. High doses of radiation produce immunosuppression, mainly due to the destruction of cells. Persisting effects on the immune system have been observed after irradiation. At low doses and dose rates, the effects of ionizing radiation on the immune system may be suppressive or stimulatory. The long term impacts of low doses of radiation on immune functions in relation to human health need to be evaluated.

4.5. Cardiovascular and other health effects besides cancer

The 2006 UNSCEAR report of also considered epidemiological investigations which addressed diseases other than cancer, principally cardiovascular disease. There is an increased risk of cardiovascular disease associated with high radiation doses to the heart which may be incurred during radiotherapy. To date, evidence for an association between fatal cardiovascular disease and radiation exposure at doses of less than about 1–2 Gy exists only in data on Japanese atomic bomb survivors. Other studies are not clear or are inconsistent. The committee judged that overall data are not sufficient to determine appropriate risk models for these end points, nor to conclude there is a causal relationship between irradiation and the incidence of cardiovascular disease for doses of less than about 1–2 Gy. Because there are many confounding factors, it is unlikely that epidemiology alone will aid in understanding the potential for and nature of any causal relationship.

4.6. Risks from radon exposure

UNSCEAR has also specifically reviewed the latest evidence regarding risk related to radon exposure and to its decay products. Studies of miners provide a strong basis for evaluating radon exposure risk and for investigating the effects of modifiers to the dose response relationship. The extrapolation of radon concentrations in the air in mines to those in homes provides an indirect basis for assessing risks from residential exposure to radon. However there have now been over 20 direct analytical studies of exposure to residential levels of radon and lung cancer. Recent pooled studies support a small but detectable increase in lung

cancer risk from residential exposure. Because of the synergistic interaction between effects of radon exposure and inhalation of tobacco smoke, smokers account for nearly 90% of the averaged risk population from residential exposure to radon.

4.7. Effects on non-human biota

In its 1996 scientific report, UNSCEAR evaluated rates of exposure below which effects on populations of species other than humans were unlikely. The committee's 2008 assessment has since reviewed approaches to evaluating doses to species other than humans, together with new scientific information on radiobiological effects on plants and animals (in particular information from continuing follow-up of environmental consequences of the Chernobyl accident). That review has revealed no evidence to support changing the conclusions of the 1996 report. Reproductive changes are more important indicators than mortality, and mammals are the most sensitive organisms. No effects are expected at chronic dose rates below 0.1 mGy/h or at acute doses below 1 Gy for the most highly affected individuals in the exposed population.

5. CONCLUSIONS

UNSCEAR has completed a wide-ranging review of health effects, including new epidemiological evidence involving longer follow-up and improved dosimetry, and the results of cellular, genetic and microbiological studies. While differences exist at the detail level, the overall risk factors for radiation exposure remain essentially unchanged.

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STATUS OF LEVELS AND EFFECTS OF NON-IONIZING RADIATION

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Abstract

A number of new technologies generate non-ionizing radiation (NIR), including electromagnetic fields (EMF) from 0 to 300 GHz, and optical and ultraviolet (UV) radiation. With increasing environmental and professional exposure to NIR, the question posed by scientists as well as governments and the general public has been whether the biological effects observed for different types of non-ionizing radiation represent a health risk. This paper provides a review of current environmental levels of EMF and ultraviolet radiation and summarizes the health effects and risks known to date. While research on EMF is ongoing, a number of national authorities have adopted international exposure guidelines to protect both the public and workers from known adverse effects of EMF, and are supporting research to fill knowledge gaps. With respect to UV radiation, which presents a clear and measurable health risk, preventive measures have been successfully promoted and implemented.

1. INTRODUCTION

As estimated by the World Health Organization (WHO), proper environmental management is the key to avoiding the quarter of all preventable illnesses directly caused by environmental factors. [1] As many as 13 million deaths can be prevented every year by making our environment healthier. The environment influences our health in many ways — through exposure to physical, chemical and biological risk factors, and through related changes in our behaviour in response to those factors. Radiation is one of the physical factors that contribute to this global burden of disease.

Different types of radiation may be produced, i.e. ionizing and non-ionizing radiation. Ionizing radiation refers to particles that have a high enough energy to interact with the atoms of a target. Non-ionizing radiation (NIR) refers to any type of electromagnetic radiation that does not carry enough energy per quantum to ionize atoms or molecules. Near ultraviolet, visible light, infrared, radiofrequency (RF) fields, and extremely low frequency (ELF) fields are all examples of non-ionizing radiation.

As societies develop, a number of new technologies generate non-ionizing radiation, including electromagnetic fields (EMF) from 0 to 300 GHz, and optical and ultraviolet (UV) radiation. This is especially the case in industry, transport, power transmission, telecommunications, high energy physics research and medicine. Unfortunately, this rapid technological development and its widespread application to medicine and other areas is significantly in front of appropriate epidemiological and biological research and the development of proper health risk assessment.

With increasing environmental and professional exposure to non-ionizing radiation, the question posed by scientists as well as governments and the general public has been whether the biological effects observed for different types of non-ionizing radiation represent a health risk. This paper provides a review of current levels and effects from electromagnetic fields and ultraviolet radiation.

2. EXPOSURE LEVELS OVER THE NIR SPECTRUM

Exposure to NIR has been increasing over the past couple of decades with a number of man-made applications over the electromagnetic (EMF) spectrum, ranging from static fields (0 Hz) through extremely low frequency (ELF) fields, and radiofrequency (RF), as well as over the optical and UV spectrum.

2.1. Static Fields

Electric and magnetic fields are generated by phenomena such as the Earth's magnetic field, thunderstorms, and the use of electricity. When such fields do not vary with time they are referred to as static and have a frequency of 0 Hz.

In the atmosphere, static **electric** fields (also referred to as electrostatic fields) occur naturally in fair weather, and more strongly in association with thunderclouds. Friction can also separate positive and negative charges and generate strong static electric fields. Their strength is measured in units of volt per metre, (V/m), or kilovolt per metre (kV/m). In daily life we may experience spark discharges with grounded objects or hair rising as a result of friction, for example from walking on a carpet. The use of DC electricity is another source of static electric fields, e.g. rail systems using DC, and televisions and computer screens with cathode ray tubes.

A static **magnetic** field is measured in units of ampere per metre (A/m), but is usually expressed in terms of the corresponding magnetic induction measured in units of tesla, (T) or millitesla (mT).The natural geomagnetic field varies over the Earth's surface between about 0.035–0.07 mT and is perceived by certain animals that use it for orientation. Human-made static magnetic fields are

generated wherever DC currents are used, such as in electric trains or industrial processes like aluminium production and gas welding. These can be more than 1000 times stronger than the Earth's natural magnetic field.

Recent technological innovations have led to the use of magnetic fields up to 100 000 times stronger than the Earth's magnetic field. They are used in research and in medical applications such as magnetic resonance imaging (MRI), which provides three dimensional images of the brain and other soft tissues. In routine clinical systems, scanned patients and machine operators can be exposed to strong magnetic fields in the range of 0.2–3 T. In medical research applications, higher magnetic fields — up to about 10 T — are used for whole body patient scanning.

For static electric fields, few studies have been carried out. The results to date suggest the only acute effects are associated with body hair movement and discomfort from spark discharges. Chronic or delayed effects of static electric fields have not been properly investigated.

2.2. Extremely low frequency (ELF) fields

For the sake of this paper, extremely low frequency fields (ELF) are defined as fields above 0 Hz and less than 100 kHz. Since the late 1970s, questions have been raised whether exposure to these extremely low frequency (ELF) electric and magnetic fields (EMF) produces adverse health consequences. Since then, much research has been done, successfully resolving important issues and narrowing the focus of future research.

Electric and magnetic fields exist wherever electric current flows — in power lines and cables, residential wiring and electrical appliances. **Electric** fields arise from electric charges, are measured in volts per metre (V/m) and are shielded by common materials, such as wood and metal. **Magnetic** fields arise from the motion of electric charges (i.e. a current), are expressed in tesla (T), or more commonly in millitesla (mT) or microtesla (μT). In some countries another unit called the gauss (G) is commonly used (10 000 G = 1 T). These fields are not shielded by most common materials, passing easily through them. Both types of fields are strongest close to the source and diminish with distance.

Most ELF fields arise from the transmission and use of electrical energy at power frequencies of 50/60 Hz. Most electric power operates at a frequency of 50 or 60 cycles per second, or hertz (Hz). Close to certain appliances, magnetic field values can be in the order of a few hundred microtesla. Underneath power lines, magnetic fields can be about 20 μT and electric fields can be several thousand volts per metre. However, average residential power frequency magnetic fields in homes are much lower — about 0.07 μT in Europe and 0.11 μT in North America. Mean values of the electric field in homes are up to several tens of volts per metre.

2.3. Radiofrequency (RF) fields

Radiofrequency (RF) fields, defined herein as waves from 100 kHz to 300 GHz, are used in many applications including: FM radio (30–300 MHz), mobile telephones, television broadcast, microwave ovens, medical diathermy (0.3–3 GHz), radar, satellite links and microwave communications (3–30 GHz).

There has been concern about possible health consequences from exposure to the RF fields produced by wireless technologies, and particularly by mobile telephony, now commonplace around the world. In many countries, over half the population use mobile phones and the market is growing rapidly. At the end of 2007, there were more than 3.3 billion mobile phone subscribers. In some parts of the world, they are the most reliable or only phones available.

Other wireless networks that allow high speed internet access and services, such as wireless local area networks (WLANs), are also increasingly common in homes, offices, and many public areas (airports, schools, residential and urban areas). As the number of base stations and local wireless networks increases, so does RF exposure to the population. Recent surveys have shown that the RF exposure from base stations range from 0.002% to 2% of the levels of international exposure guidelines, depending on a variety of factors such as proximity to the antenna and the surrounding environment. This is lower or comparable to RF exposure from radio or television broadcast transmitters.

Mobile phone handsets and base stations present quite different exposure situations. RF exposure to a mobile phone user is far higher than to a person living near a cellular base station. However, apart from infrequent signals used to maintain links with nearby base stations, the handset transmits RF energy only while a call is being made, whereas base stations are continuously transmitting signals.

Mobile phone handsets are low powered RF transmitters, emitting maximum powers in the range of 0.2 to 0.6 watts. The RF field strength (and hence RF exposure to a user) falls off rapidly with distance from the handset. Therefore, the RF exposure to a user of a mobile phone located tens of centimetres from the head (using a ‘hands free’ appliance) is far lower than to a user who places the headset against the head. RF exposure to nearby people is very low.

Base stations transmit power levels from a few watts to 100 watts or more, depending on the size of the region or ‘cell’ they are designed to service. Typically within 2–5 metres of antennas mounted on rooftops, fences keep people away from places where RF fields exceed exposure limits. Since antennas direct their power outward, and do not radiate significant amounts of energy from their back surfaces or towards the top or bottom of the antenna, the levels of RF energy inside or to the sides of a building with an antenna are normally very low.

Other RF sources in the community, such as paging and other communications antennas used by fire, police and emergency services, operate at similar power levels as cellular base stations, and often at a similar frequency.

In many urban areas television and radio broadcast antennas commonly transmit higher RF levels than do mobile base stations. Due to their lower frequency, at similar RF exposure levels, the body absorbs up to five times more of an FM radio or television signal than that transmitted by a base station. This is because the frequencies used in FM radio (around 100 MHz) and in TV broadcasting (around 300 to 400 MHz) are lower than those employed in mobile telephony (900 MHz and 1800 MHz) and because a person's height makes the body an efficient receiving antenna.

2.4. Ultraviolet (UV) radiation

In describing the biological effects of optical radiation, the spectrum is frequently divided into seven photobiological spectral bands (CIE 1999). The ultraviolet spectral bands are: UVC (100–280 nm), UVB (280–315 nm), and UVA (315–400 nm). The sun is by far the strongest source of ultraviolet radiation in our environment. Other man-made sources are used mostly in industry (e.g. specialized lamps and welding arcs) and for cosmetic purposes, such as tanning beds.

As sunlight passes through the atmosphere, all UVC and most UVB are absorbed by ozone, water vapour, oxygen and carbon dioxide. UVA is not filtered as significantly by the atmosphere.

Natural UV radiation levels are influenced by a number of physical factors, such as sun elevation (the higher the sun in the sky, the higher the UV radiation level), latitude (the closer to the equator, the higher the UV radiation levels), cloud cover (UV radiation levels are highest under cloudless skies but even with cloud cover, they can be high) and altitude (UV levels increase by about 5% with every 1000 metres of altitude). Ozone absorbs some UV radiation from the sun, and as the ozone layer is depleted, more UV radiation reaches the Earth's surface. Also, many surfaces reflect the sun's rays and add to overall UV exposure (e.g. grass, soil and water reflect less than 10% of UV radiation; fresh snow reflects up to 80%; dry beach sand reflects 15%, and sea foam reflects 25%).

3. HEALTH EFFECTS OVER THE NIR SPECTRUM

There have been questions raised about the potential health impact of electromagnetic fields. A number of national and international agencies have planned and executed research agendas to address those concerns. This research

includes basic mechanistic studies to understand biological effects at the cellular level, animal studies to examine effects on whole organisms at high levels of exposure or for prolonged periods, as well as human studies in laboratory settings and epidemiological retrospective studies. Publicly funded research has increasingly been designed not only to address emerging scientific questions, but also to allay public fears.

3.1. Static Fields

In the case of static magnetic fields, acute effects are only likely to occur when there is movement within the field, such as motion by a person or an internal body movement, like blood flow or heart beat. [2, 3] A person moving within a field above 2 T can experience sensations of vertigo and nausea, and sometimes a metallic taste in the mouth and perceptions of light flashes. Although only temporary, such effects may have a safety impact on workers executing delicate procedures (such as surgeons performing operations within MRI units).

Static magnetic fields exert forces on moving charges in the blood, such as ions, generating electrical fields and currents around the heart and major blood vessels that can slightly impede the flow of blood. Possible effects range from minor changes in heartbeat to an increase in the risk of abnormal heart rhythms (arrhythmia) that might be life threatening (such as ventricular fibrillation). However, these types of acute effects are only likely within fields in excess of 8 T.

It is not possible to determine whether there are any long term health consequences from exposure in the millitesla range because, to date, there are no well conducted epidemiological or long term animal studies. Thus the carcinogenicity of static magnetic fields to humans is not at present classifiable (IARC, 2002).

3.2. Extremely low frequency (ELF) fields

At present, there do not seem to be substantive health issues related to ELF electric fields at levels generally encountered by members of the public. Thus only the effects of exposure to ELF magnetic fields are described below, based on a recent health risk assessment published by the World Health Organization. [4]

3.2.1. Short term effects

There are established biological effects from acute exposure at high levels (well above 100 μT) explained by recognized biophysical mechanisms: external ELF magnetic fields induce electric fields and currents in the body which, at very

high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system.

3.2.2. Potential long term effects

Much of the scientific research examining long term risks from ELF magnetic field exposure has focused on childhood leukaemia. In 2002, IARC published a monograph classifying ELF magnetic fields as 'possibly carcinogenic to humans'. [3] Additional studies since then do not alter the status of this classification. This classification is used to denote an agent for which there is limited evidence of carcinogenicity in humans and less than sufficient evidence for carcinogenicity in experimental animals (other examples include coffee and welding fumes). The classification was based on pooled analyses of epidemiological studies consistently demonstrating a two fold increase in childhood leukaemia associated with an average exposure to residential power frequency magnetic fields above 0.3 to 0.4 μT.

However, epidemiological evidence is weakened by methodological problems, such as potential selection bias. In addition, there are no accepted biophysical mechanisms that would suggest that low level exposure is involved in cancer development. Thus, if there were any effects from exposure to these low level fields, it would have to be through a biological mechanism that is as yet unknown. Additionally, animal studies have been largely negative. Thus, on balance, the evidence related to childhood leukaemia is not strong enough to be considered causal.

Childhood leukaemia is a comparatively rare disease with a total annual number of new cases estimated at 49 000 worldwide in 2000. Average magnetic field exposure of above 0.3 μT in homes is rare: it is estimated that only between 1% and 4% of children live in such conditions. If the association between magnetic fields and childhood leukaemia is causal, the number of cases worldwide that might be attributable to magnetic field exposure is estimated to range from 100 to 2400 cases per year, based on values for the year 2000, representing 0.2% to 4.95% of total incidence for that year. Thus, if ELF magnetic fields actually do increase the risk of the disease, when considered in a global context, the impact on public health of ELF EMF exposure is limited.

A number of other adverse health effects have been studied in possible association with ELF magnetic field exposure. These include other childhood cancers, cancers in adults, depression, suicide, cardiovascular disorders, reproductive dysfunction, developmental disorders, immunological modifications, neurobehavioural effects and neurodegenerative disease. The scientific evidence supporting an association between ELF magnetic field exposure and all of these health effects is much weaker at the moment than for childhood leukaemia. In

some instances (i.e. for cardiovascular disease or breast cancer) evidence suggests that these fields do not cause them.

3.3. Radiofrequency (RF) fields

A large number of studies have been performed over the last decade to assess whether RF fields, particularly mobile phones and their base stations, pose a potential health risk.

A common concern regarding base station and local wireless network antennas relates to the possible long term health effects that whole body exposure to RF signals may have. To date, the only health effect from RF fields identified in scientific reviews is related to an increase in body temperature (>1°C) from exposure at very high field intensity found only in certain industrial facilities, such as RF heaters. The levels of RF exposure from base stations and wireless networks are so low that the temperature increases are insignificant and do not affect human health.

3.3.1. Cancer

Mobile phones: Much scientific research examining long term risks from RF field exposure has focused on brain and other tumours of the head. A large epidemiology study, INTERPHONE, has been coordinated in 13 countries by the International Agency for Research on Cancer (IARC) — a specialized cancer research agency of WHO — to identify whether there are links between mobile phone use and head and neck cancers. Results of national data from several participating countries have been published and the international pooled analysis is anticipated to be published soon. So far, it appears that mobile phone use within a 10 year span does not increase the risk of head tumours. In regards to longer term use, there are indications of an increase in certain cancer risks for heavy users. However, data are sparse and recall bias is considered significant. At present, there is no epidemiological data regarding children and adolescents.

Base stations: Media or anecdotal reports of cancer clusters around mobile phone base stations have heightened public concern. It should be noted that geographically, cancers are unevenly distributed among any population. Given the widespread presence of base stations in the environment, it is expected that possible cancer clusters will occur near base stations merely by chance. Moreover, the reported cancers in these clusters are often a collection of different types of cancer with no common characteristics and hence unlikely to have a common cause.

Scientific evidence on the distribution of cancer in the population can be obtained through carefully planned and executed epidemiological studies. Over

the past 15 years, studies examining a potential relationship between RF transmitters and cancer have been published. These studies have not provided evidence that RF exposure from transmitters increases the risk of cancer. Likewise, long term animal studies have not established an increased risk of cancer from exposure to RF fields, even at levels are much higher than those produced by base stations and wireless networks.

3.3.2. Other effects

Few studies have investigated general health effects in individuals exposed to RF fields. This is because of the difficulty in distinguishing possible health effects from the very low signals emitted by base stations from other, higher strength RF signals in the environment. Most studies have focused on the RF exposure of mobile phone users. Human and animal studies examining brain wave patterns, cognition and behaviour after exposure to RF fields, such as those generated by mobile phones, have not identified adverse effects. RF exposure used in these studies were about 1000 times higher than that associated with general public exposure from base stations or wireless networks. No consistent evidence of altered sleep or cardiovascular function has been reported. In general, recent rigorous studies do not replicate the positive findings of earlier studies, but a few positive effects are reported. Research has failed to provide consistent support for a relationship between self reported symptoms and electromagnetic hypersensitivity.

3.4. Ultraviolet (UV) radiation

Small amounts of UV radiation are beneficial to health, and play an essential role in the production of vitamin D. However, excessive exposure to UV radiation is associated with different types of skin cancer, sunburn, accelerated skin ageing, cataract and other eye diseases. There is also evidence that UV radiation reduces the effectiveness of the immune system. Many of the adverse health effects of UV exposure have been characterized on the basis of traditional outdoor sun exposure. However, as recently documented, tanning beds also present the same risks to health, including cancer. [5]

3.4.1. Effects on the skin

Excessive UV exposure results in a number of chronic skin changes:

- Cutaneous malignant melanoma: a life-threatening malignant skin cancer;
- Squamous cell carcinoma of the skin: a malignant cancer, which generally progresses less rapidly than melanoma and is less likely to cause death;

- Basal cell carcinoma of the skin: a slow-growing skin cancer appearing predominantly in older people;
- Photoageing: a loss of skin tightness and the development of solar keratoses.

3.4.2. Effects on the eyes

Acute effects of UV radiation include photokeratitis and photoconjunctivitis (inflammation of the cornea and conjunctiva, respectively). These effects are reversible, easily prevented by protective eyewear and are not associated with any long term damage.

Chronic effects of UV radiation include:

- Cataract: an eye disease in which the lens becomes increasingly opaque, resulting in impaired vision and eventual blindness;
- Pterygium: a white or creamy fleshy growth on the surface of the eye;
- Squamous cell carcinoma of the cornea or conjunctiva: a rare tumour of the eye surface.

3.4.3. Other health effects

UV radiation appears to diminish the effectiveness of the immune system by changing the activity and distribution of cells responsible for triggering immune responses. Immunosuppression can cause reactivation of the herpes simplex virus in the lip (‘cold sores’).

4. DISCUSSION

While we benefit from the use of technologies relying on non-ionizing radiation, it is important to continue to research, assess and monitor any potential adverse health effects.

With respect to EMF, a number of national authorities are supporting research programmes to fill knowledge gaps, and have adopted exposure limits to protect both the public and workers from established adverse effects of EMF. International exposure guidelines for NIR protection have been developed by the International Commission on Non-Ionizing Radiation Protection (ICNIRP) and the Institute of Electrical and Electronics Engineers (IEEE/ICES). For static fields, present limits are based on avoiding sensations of vertigo and nausea induced by movement within a static magnetic field. The limits for external ELF magnetic fields are based on induction of internal electric fields and currents in

the body which, at very high field strengths, cause nerve and muscle stimulation and changes in nerve cell excitability in the central nervous system. Regarding RF fields, limits are set to prevent health effects related to an increase in body temperature (>1°C) from exposure to a very high field intensity found only in certain industrial facilities, such as RF heaters.

With regard to UV radiation, scientific evidence has established that there are clear and proven health risks. These risks can be easily prevented through personal protective measures from solar UV exposure, e.g. adequate clothing, hat, sunscreen and sunglasses. Such preventive policy measures have been successfully promoted and implemented at the country level in many parts of the world.

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SPECIAL PLENARY SESSION

LOW DOSE AND LOW DOSE RATE RADIATION EFFECTS AND MODELS. SUMMARY OF NATIONAL COUNCIL ON RADIATION PROTECTION AND MEASUREMENTS NCRP FORTY FOURTH ANNUAL MEETING (14–15 APRIL 2008 IN BETHESDA, MARYLAND, USA

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Abstract

This paper summarizes the highlights of presentations at the 44th Annual National Council on Radiation Protection and Measurements (NCRP) Annual Meeting, primary conclusions drawn by the speakers, and future activities of NCRP in analysing the biological and potential human health effects of exposure to low doses of ionizing radiation. A related subject discussed by speakers at the meeting was the effect of the rate of delivery of radiation doses (i.e., dose rate). The goal of the 2008 NCRP Annual Meeting was to bring these subjects into the perspective of currently available data and models of the biological responses and human health impacts of exposure to low doses of radiation. Views of the public and the role of growing knowledge of low dose radiation effects on regulatory decision making were also discussed. Future plans by the NCRP to continue its analysis of biological and human health effects of low dose and low dose rate ionizing radiation are described.

1. INTRODUCTION

One of the most highly debated subjects in life sciences research is the response of living systems to low doses of radiation, especially when the doses are delivered at the low rates characteristic of most human exposure. The 2008 NCRP Annual Meeting addressed many of the primary issues related to low dose radiation effects and models, and the advances in knowledge from recent laboratory research results, human epidemiology studies, and theoretical modeling of radiation interactions at the molecular, cellular and tissue levels. The Annual Meeting was attended by nearly 500 research scientists, government regulators, and others interested in the biological effects and human health and regulatory implications of studies on low dose radiation. Presentations from the 2008 NCRP Annual Meeting can be obtained at http://NCRPpublications.org, and the proceedings will be published in Health Physics in 2009.

2. MEETING HIGHLIGHTS

Highlights of the meeting included the following.

2.1. Keynote lecture

Dr. Dudley Goodhead (Medical Research Council, United Kingdom) presented the 5th annual Warren K. Sinclair Keynote Lecture on "Issues in Quantifying the Effects of Low Level Radiation", in which he reviewed the rapidly expanding knowledge on physical interactions of ionizing radiation with DNA and other cellular structures. Dr. Goodhead emphasized the importance of complex DNA base damage and strand break events in producing non-repairable or slowly repairable cellular damage.

2.2. Lauriston Taylor lecture on the Yucca Mountain Nuclear Waste Repository

Dr. Dade Moeller (Dade Moeller and Associates, New Bern, North Carolina, USA) presented in the 32nd Lauriston Taylor Lecture, a historically interesting and insightful evaluation of the potential value and public debate over the use of Yucca Mountain as a repository for spent nuclear fuel from United States of America reactor facilities. He discussed the radionuclides to be stored in the facility in terms of potential health effects to those living and working near the facility, and the issues to be given consideration over a period of many millennia in terms of release of radionuclides from the facility and their health impacts. He reviewed the proposed regulatory restrictions on doses to the public from the facility, and made a strong argument that the prediction of health risks over tens of thousands of years resulting from releases of radionuclides from the Yucca Mountain facility cannot be accurately made at the present time, nor should these potential risks be the subject of long term regulations by federal agencies.

2.3. Debate on LNT model of radiation response

A stimulating debate was held between Dietrich Averbeck (Institut Curie, France) and David Brenner (Columbia University, New York, USA) on the topic of "Does Scientific Evidence Support a Change from the Linear Non-threshold (LNT) Model for Low Dose Radiation Risk Extrapolation". Dr. Averbeck represented the position of the 2005 French Academy of Sciences Report which argued that current evidence from laboratory studies supports the existence of a threshold dose response to radiation, whereas Dr. Brenner supported the conclusion of the 2006 National Academy of Sciences BEIR VII report that

existing evidence is consistent with a non-threshold linear dose response model. Neither debater scored a clear victory, but the results provided strong support for the need to conduct additional research to resolve the issue of whether the LNT model is appropriate for evaluating human health effects at low radiation doses.

2.4. Summary of presentations on laboratory and epidemiological studies

Two major sessions of the 2008 Annual Meeting led to valuable insights into the potential biological and human health effects of low radiation doses. These sessions included presentations in the following areas:

2.4.1. Life sciences research on low dose radiobiology

Dr. William Morgan (Pacific Northwest National Laboratory, Richland, Washington, USA) presented evidence that nontargeted effects of radiation such as genomic instability and bystander effects must be considered in evaluating the responses of cells and tissues to low dose radiation. Dr. Michael Cornforth (University of Texas Medical Branch, Galveston, Texas, USA) and Dr. Andrew Wyrobek (Lawrence Berkeley National Laboratory, Berkeley, California, USA) presented evidence that chromosomal aberrations and resulting changes in gene expression are important factors in determining cellular responses to radiation. Dr. Peggy Jeggo (University of Sussex, United Kingdom) discussed DNA damage and repair in the context of evaluating the risk from radiation exposure. Dr. Mary Helen Barcelos-Hoff (Lawrence Berkeley National Laboratory, Berkeley, California, USA) presented strong arguments based on laboratory studies that the response to low dose radiation should be viewed from the perspective of integrated tissue responses rather than from effects measured only on single cells. Dr. Ann Kennedy (University of Pennsylvania School of Medicine, Philadelphia, Pennsylvania, USA) discussed a variety of factors that can influence radiation response both *in vitro* and *in vivo*, including dietary factors, drugs, hormones, vitamins, oxidative stress, anti-oxidants, and exposure to cancer promoting and suppressing agents. Evidence for sensitivity to radiation carcinogenesis associated with genetic susceptibility was summarized by Dr. Joel Bedford (Colorado State University, Ft. Collins, Colorado, USA). Based on research involving life-span studies with dogs exposed acutely or chronically to external ^{60}Co radiation or internal beta-gamma emitting radionuclides, Dr. Antone Brooks (Washington State University Tri-Cities Campus, Richland, Washington, USA) summarized data on cancer risk estimates in relation to radiation dose, dose rate and dose distribution in the body. A broad biophysical approach to combining experimental data and theoretical models in the development of systems biology concepts for describing the response of living

systems to low radiation doses was presented by Dr. Herwig Paretzke (Institut für Strahlenschutz, Neuherberg, Germany).

2.4.2. Epidemiological studies on human health effects

Dr. Charles Land (National Cancer Institute, Bethesda, Maryland, USA) presented an informative overview of human health risks of exposure to radiation in occupational, medical, accidental and A-bomb settings, and discussed the uncertainties associated with the prediction of health effects of low dose radiation exposure based on the results of epidemiological studies on these exposed populations. He also described the views of individuals and population subgroups on the beneficial and adverse outc omes of exposure from medical and other exposure.

Dr. Roy Shore (Radiation Effects Research Foundation, Hiroshima, Japan) summarized radiation risk information gained from radiation workers involved in cleanup after the Chernobyl nuclear accident, workers at nuclear facilities in Russia, the United States of America and elsewhere, and individuals exposed to low doses of radiation from medical procedures. He compared the estimates of cancer risk obtained from studies on these populations to those obtained for Japanese survivors who were acutely exposed to radiation from the atomic bombs detonated in Japan in 1945. He concluded that studies on humans exposed to low radiation doses have so many dosimetric uncertainties and limitations in statistical power that clear conclusions on cancer risk from such exposure cannot be drawn using available data. Dr. Shore also discussed the influence of individuals who are particularly susceptible to radiation cancer induction on estimation of the aggregate human risk of exposure to low radiation doses.

Dr. Ethel Gilbert (National Cancer Institute, Bethesda, Maryland, USA) concluded the discussion of human health effects with an insightful discussion on complications in determining radiation dose response relationships for cancer induction that result from uncertainties in dosimetry for exposed populations.

2.5. Regulatory implications of low dose radiation exposure effects and models

2.5.1. Regulatory implications of studies on effects of low radiation exposure

An important long range outcome of study results on low dose and low dose rate radiation biological effects and human health implications is the possibility of future changes in regulatory controls on human exposure in occupational, medical and public scenarios. The final session of the 2008 NCRP Annual Meeting focused on this topic, and was initiated with a discussion by Dr. Paul

Locke (Johns Hopkins School of Public Health, Baltimore, Maryland, USA) on public perceptions of radiation risk and the evolution of radiation regulations over the past century. His introductory presentation was followed by talks from representatives of the Nuclear Regulatory Commission (Mr. Martin Virgilio, NRC, Rockville, Maryland, USA), the Department of Energy (Dr. Noelle Metting, United States of America DOE, Washington, DC, USA) and the United States of America Environmental Protection Agency (Dr. Juan Reyes, United States of America EPA, Washington, DC, USA) on the agencies' views on potential changes in regulatory radiation exposure limits which could be introduced as a result of well documented scientific information on dose response relationships regarding exposure to low radiation doses.

2.5.2. Public views of radiation risk and combining scientific knowledge with decision making

Dr. Hank Jenkins-Smith (University of Oklahoma, Jenkins, Oklahoma, USA) presented informative comparisons of scientists' views as well as those of members of the public in the United States of America and European nations on radiation risks and the potential benefits of nuclear energy. In general, surveys conducted in the 2002–2007 period uncovered little or no difference in scientists' beliefs in the United States of America and Europe about radiation dose response relationships, with about 20% and 70% supporting linear and sublinear threshold models, respectively. Perceived risks of nuclear power accidents were higher among the public in the United States of America than among scientists surveyed in both the United States of America and European nations. However, support for nuclear power as an energy resource was as high among members of the United States of America public as among scientists. In general, the support for nuclear power was significantly higher among scientists from France, where nuclear power is a major source of energy, than in the United States of America, England, Germany and other nations in the European Union.

Dr. Paul Ziemer (Purdue University (retired), West Lafayette, Indiana, USA) summarized the United States of America federal programmes that are in progress to reimburse public and occupational claims of radiation exposure related health effects which have been filed by former energy workers involved in the production of nuclear weapons, military veterans involved in atmospheric nuclear testing and the occupation of Japan after A-bomb detonations in 1945, and members of the public living downwind of atmospheric nuclear test locations.

The final presentation of the meeting was given by Dr. John Poston, Sr. (Texas A&M University (retired), College Station, Texas, USA), on combining scientific knowledge with decision making in the aftermath of nuclear and

radiological accidents and incidents, including acts of terrorism involving radioactive materials.

2.6. Primary insights into biological and health effects of low dose radiation exposure

Overall, the 2008 NCRP Annual Meeting provided an up to date view of contemporary knowledge on radiation effects and models of radiation dose response relationships, and also pointed to the implications of this knowledge as a framework for evaluating potential human health effects. Information presented at the meeting also provided clear insights into future research needs required to obtain an improved understanding of the biological interactions and health effects of low doses of ionizing radiation, including exposure at the low dose rates typical of many occupational and public environments. The following is a concise summary of the highlights of new findings and areas of continuing research related to low dose and low dose rate biological and human health effects.

2.6.1. Epidemiology studies

Several factors limit the precision of epidemiological data in defining cancer risk and other health effects at low radiation doses. These factors include: (a) a much larger sample size is required at low dose levels to attain adequate statistical power to define dose response characteristics; (b) confidence levels for estimates of excess relative risk per Gy become much wider at low dose levels; (c) studies at low dose levels have a greater percentage of ‘false positive’ and ‘false negative’ results; (d) many sources of errors in measured and calculated external, internal and organ doses influence dose response modeling; (e) national origin, age at exposure, gender, inherent genetic susceptibility, exposure to cancer promoters and other environmental risk factors, as well as lifestyle factors (diet, drugs, tobacco use, intake of antioxidants, etc.) all influence individual risks of cancer and other diseases.

2.6.2. Experimental studies

Significant advances have been made during the past decade in gaining increased knowledge of biological effects of low doses of radiation. These include:

(i) Molecular pathways of low dose radiation damage and repair to DNA and chromosomes

Significant knowledge gained from studies in recent years includes: (a) low energy secondary electrons from photon irradiation (~ 30% of dose) can produce complex clustered double strand break (DSB) damage, which is the least repairable type of damage and can lead to DNA losses and rearrangements; (b) non-homologous end joining (NHEJ) at the DSB site is a more important repair pathway than homologous recombination events; (c) signaling factors such as ATM kinase play a key role in initiating DNA repair processes that depend on Artemis nuclease and other factors; (d) DSB introduces both S/G2 and G2/M cell cycle checkpoints which provide time and signals for initiating repair pathways, but cells can have as many as 10 unrepaired DSB and enter mitosis, which is a possible mechanism for later expression of genetic damage in progeny cells; (e) low and high doses of radiation have similar effects on gene expression in mouse and human cells; and low doses ($\leq$ 100 mGy) have some notably different transcriptional effects than higher doses on genes involved in cell cycle regulation, cell cell interactions, oxidative stress responses, and protein and fatty acid metabolism; (f) low and high radiation doses affect expression of the same genes in human and mouse cells, but results of studies on mice irradiated in vivo show significant tissue specific variations in effects on gene expression; (g) dicentrics, complex translocations, inversions and deletions all provide indications of radiation damage, but dicentrics remain the usual assay for low dose radiation effects; (h) not only chromosome dicentrics and translocations are indicators of mutation and potential neoplastic transformation, inversions and interstitial deletions on chromosomes can serve as predictive markers.

(ii) Factors modifying response to low radiation doses

Several biological factors have been demonstrated to modify response to low radiation doses. These include:

- **Bystander effects:** Adverse responses, including cytogenetic effects and cell death, in cells not directly 'hit' by radiation are known as bystander effects. These effects have been successfully demonstrated by α-particle microbeam experiments and other radiation modalities. Mechanism(s) for transmission of signals from hit cells to neighboring cells remain under study, but could include cell to cell transmission of molecular factors (e.g., cytokines) via gap junctions or release of these factors into blood or tissue fluids.

- **Genomic instability:** Many experimental studies have demonstrated that delayed genomic effects in the progeny of 'hit' cells can be manifested by effects such as chromosome alterations, mutation, changes in gene expression, and cell death.
- **Radioadaptive responses**: Small priming doses (≤50 mGy) have been demonstrated to reduce adverse effects of larger challenge doses (e.g., less cytogenetic damage, cell death, and carcinogenic risk). Upregulation of TP53 and MYC genes through low doses may be a 'switch' increasing transcription of a broad array of other genes involved in protective responses to larger challenge doses. Low dose radiation produces adaptive responses that have been found in experimental systems to reduce the frequency of chromosomal alterations and cell mutation as well as transformation below the spontaneous level.
- **Integrated tissue responses:** Studies with epithelial tissue models *in vitro* have demonstrated that low radiation doses (≤100 mGy) can induce dysfunctional cell–cell and cell–extracellular matrix interactions that lead to heritable phenotypic changes characteristic of malignancy; the 'trigger' is a radiation induced elevation in transforming growth factor, which serves to sustain extracellularly regulated activation of kinases at the integrated tissue level. These effects are well characterized by a 'systems biology' modeling approach.
- **Genetic susceptibility:** Although relatively small groups of people have well documented diseases associated with susceptibility to radiation induced cancer (e.g., ataxia-telangiectasia and retinoblastoma), it is expected that the fraction of humans with uncharacterized sensitivity to radiation may be much larger (perhaps 20% or more). Many laboratory, animal based studies have clearly demonstrated the effects of defined genetic mutations on susceptibility to radiation carcinogenesis. Some candidate genotypic markers of sensitivity have been identified in humans (e.g., BRCA genes in breast tissue), but progress is at an early stage.
- **Individual factors:** Many factors related to lifestyle are known to influence cancer risk, including age at exposure, gender, genetic background, exposure to cancer promoting agents and other environmental risk factors, and lifestyle factors such as diet, drugs, tobacco use, intake of antioxidants, etc.
- **Radiation quality and dose rate:** Ongoing studies on the relative biological effects (RBE) of radiation of differing qualities have continued to demonstrate the importance of this factor in evaluating the health risk of exposure to neutrons and charged particle radiation. In addition, continuing research on the influence of dose level and dose rate on biological responses to low dose radiation have demonstrated the importance of this factor in

estimating the risk of cancer and other radiation induced diseases. Although experimental studies have shown large variations in dose rate effects for different biological endpoints, a dose and dose rate effectiveness factor (DDREF) of 2.0 proposed by the International Commission on Radiological Protection and NCRP is generally consistent with existing data.

2.7. Public policy and regulatory decisions on low dose radiation exposure

The final session of the 44th NCRP Annual Meeting was focused on public views of radiation benefits and risks and the implications of new research on low dose radiation effects for the development of future radiation exposure regulations involving workers and the public.

2.7.1. Public attitudes and expectations

Concerns over public exposure from occupational, nuclear power, and many environmental sources are decreasing in the United States of America and other nations worldwide. However, concerns have been expressed recently over the rapidly growing use of radiation in medical procedures such as computed tomography (CT) imaging.

Expectations remain high that exposed members of the military (atomic veterans) and energy workers who were involved in nuclear weapons production in the United States of America will be compensated for debilitating diseases such as cancer potentially related to their prior radiation exposure.

Concerns are also high for public safety and health protection in the event of a nuclear or radiological terrorism incident.

2.7.2. Views of government regulatory agencies in the United States of America

Efforts to obtain improved knowledge of low dose radiation effects are considered an important activity with a potential impact on future guidelines for public and worker exposure limits. A major area of interest is the confirmation or development of a scientifically defensible alternative to the LNT dose response model as a basis for regulations. Research focused on characterizing the range of individual sensitivities to radiation health effects is considered to be an area of major importance. Changes in regulatory policies and practices will not occur rapidly, but will be given a high priority if changes are warranted on the basis of well documented scientific evidence and predictive models of radiation health effects.

2.8. Future plans of NCRP related to low dose biological and human health effects

A significant near term initiative of NCRP is to prepare a major report on low dose and low dose rate biological effects and implications for human health effects. The report, to be prepared in the 2010–2014 time frame, will incorporate results of extensive research worldwide and will extend analysis of low dose effects recently published by ICRP (Publication 99, 2004), the French Academy of Sciences (2005), and the United States National Academy of Sciences (BEIR VII, 2006). The primary report goals include: (a) to integrate research results into reliable predictive models of low dose radiation health effects; (b) to analyse health protection and regulatory implications of findings; and (c) to recommend effective mechanisms of communication for projected radiation risks of low dose radiation.

2.8.1. Publication of proceedings of NCRP annual meetings

Papers for proceedings of the 2008 NCRP Annual Meeting are in an advanced stage of preparation and peer review, and will be published in Health Physics in 2009.

The 45th Annual Meeting on the topic of "Future of Nuclear Power Worldwide: Safety, Health and Environment", was scheduled to be held on 2–3 March 2009 at the Hyatt Hotel Convention Center in Bethesda, Maryland (USA). Information on the meeting can be obtained from the NCRP website cited above.

Proceedings of other recent NCRP Annual Meetings can be accessed in Health Physics, including the proceedings of four other recent meetings:

2004: 40th Annual Meeting on "Advances in Consequence Management for Radiological Terrorism Events", Health Physics **89**(5) (2005) 416–588.

2005: 41st Annual Meeting on "Managing the Disposition of Low-Activity Materials", Health Physics **91**(5) (2006) 413–536.

2006: 42nd Annual Meeting on "Chernobyl at Twenty", Health Physics **93**(5) (2007) 345–595.

2007: 43rd Annual Meeting on "Advances in Radiation Protection in Medicine", Health Physics **95**(5) (2008) 461–657.

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SCIENTIFIC AREAS AND TOPICAL SESSIONS

I.1. CHARACTERIZATION OF RADIATION EXPOSURE

Under the motto "harmonization on the quantification of ionizing radiation exposure", this scientific area covered the following topics:

- External Exposure to Ionizing Radiation, with 186 papers;
- Internal Exposure, with 69 papers;
- Biological Dosimetry, with 27 papers.

TS I.1.1. External exposure to ionizing radiation

Topics on External Exposure to Ionizing Radiation included:

- Development of quantities and units (radiation weighting factors and equivalent dose, tissue weighting factors and effective dose);
- Assessment of dose from external radiation exposure;
- Computational methods (for dosimetry, determination of conversion factors, response of devices, analysis of radiation environments, assessment of uncertainties);
- Developments in instrumentation and methodology;
- Harmonization of the quantification of radiation exposure (regional and international intercalibrations and intercomparisons and quality assurance programmes);
- Monitoring and assessment of radiation fields;
- Assessment of uncertainties;
- Assessment of external dose in accidental exposures;
- Microdosimetry.

The 2007 ICRP recommendations (ICRP publication 103) only introduced minor changes affecting quantities and units, weighting factors and definitions relevant to external dosimetry. As a consequence there were few contributions in this area and discussion mainly focussed on other issues.

Computational techniques, in particular Monte Carlo, continue to be a growing area of importance. Historically Monte Carlo methods have been heavily used in the design and evaluation of techniques and in the development of phantoms for evaluation of operational quantities. These areas remain important. Artificial neural networks and genetic neural networks are increasingly being developed and optimized, particularly in the assessment of neutron doses. As the power of computational techniques improves, they are also increasingly being used to directly assess doses.

Participants discussed recent developments in dosimetric techniques such as:

- Luminescence, including thermo-luminescence, optically stimulated luminescence, LiF, Al2O3, CaSO4, Salt, etc.;
- Scintillation, including LaBr3, LaCl3 etc;
- Neutron measurement techniques, including multi-sphere spectrometry, tracks in CR-39, and activation;
- Other techniques, such as film, gel, ion chambers, electron paramagnetic resonance (EPR), electron spin resonance (ESR), etc.

The applications described covered:

- Occupational dosimetry, including the medical area, nuclear reactors, uranium mining and industry;
- The public;
- Patients in diagnostic and therapy and care/ward people;
- The environment — indoor and outdoor;
- Accidents and emergencies, including measurement, calculation and retrospective assessments.

Overall, the importance of easy to understand, accurate and validated dosimetry systems was underlined as a basic factor for rational decision making for radiation protection professionals, and in particular in maintaining the ALARA principle. Key to that is an improved understanding of uncertainties and limitations in dosimetry assessments. In particular, discussions emphasized the uncertainties of routine personal dosimeters and effects, such as anisotropic response for photons as well as the uncertainties in the neutron response of dosimeters. A large number of papers addressed the topics of national, regional and international intercomparisons. They covered all aspects of external dosimetry including dosimetry systems and services as well as computational techniques. Many focused strongly on lessons to be learned. Calibration systems and their applications were also described.

IRPA12 has shown that there continues to be much interest in external dosimetry as evidenced by the number of papers presented for this session. The fact that there were few radical new developments perhaps demonstrates maturity in the area. However, the need to improve understanding of the uncertainties of dose measurement and assessment is very important. The key outcomes were: that external dosimetry continues to be a diverse and thriving area of interest, key to monitoring and developing ALARA and that there is an increase in the use of computational techniques (basic physics to dose assessments) and in the reliability and validity of assessments.

TS I.1.2. Internal exposure

Topics on Internal Exposure included:

- Assessment of dose from internal radiation exposure including from accidental exposures;
- Current and novel biokinetic and dosimetric models;
- Assessment of uncertainties;
- Current and novel physical and mathematical phantoms;
- Internal dosimetry software;
- Developments in instrumentation and methods;
- Harmonization of the quantification of radiation exposure (regional and international intercalibrations and intercomparisons and quality assurance programmes);
- Monitoring plans (interpretation and bioassay data and uncertainties).

Key themes identified were:

- Computational methods;
- Statistical methods to assess uncertainties;
- Development of guidelines;
- Training events.

It is clear that there continues to be strong vitality and interest in the field of internal exposure. Many presentations reflected the trend towards more sophisticated scientific and mathematical methods in computational procedures, Monte Carlo methods associated with the use of voxel phantoms, and the application of more advanced statistical (notably Bayesian) approaches. Important new epidemiological studies for workers who were internally exposed are driving some developments, for example the assessment of uncertainties in internal dose. Identification of critical target tissues in organs requires close collaboration with radiobiologists and presents challenges in appropriate dose calculation. Conversely, there were relatively few reports about new experimental studies for internal dosimetry, reflecting reduced commitment to this field in many countries. However, this may change if there is a renaissance in nuclear power. Interpreting monitoring data involving complex cases requires expert judgment, and measures are being taken to achieve greater harmonization through the continued development of guidelines, intercomparison exercises and training.

An upcoming major milestone in this field in the next few years will be an ICRP publication of new documents on occupational intakes of radionuclides, which will apply the 2007 ICRP recommendations, with new voxel phantoms,

decay schemes, and biokinetics models, including the human alimentary tract model.

TS I.1.3. Biological Dosimetry

Topics on Biological Dosimetry included:

- Dose assessment by scoring unstable chromosomal aberrations (international standardization and statistical uncertainty);
- Rapid dose assessment in mass casualty incidents (biodosimetry, triage, automation, networking, biological dosimetry of victims exposed to very high doses, dicentric calibration curves, PCC — chemically induced — techniques, and EPR);
- Biological dosimetry networks (reference and deployable laboratories, QA programmes);
- Novel biomarkers (h2ax-loci, whole blood microarrays for radiation injury specific genes, radiation induced protein biomarkers);
- Retrospective assessment of radiation exposure (FISH, EPR).

Key themes identified were:

- Methods for use with low dose (about < 50 mGy) for acute exposure, such as premature chromosome condensation (PCC);
- Methods for use with retrospective dosimetry for acute or chronic exposure, such as fluorescence in situ hybridization (FISH).

The application of several techniques other than dicentric analysis, such as EPR and PCC, as well as translocation, was encouraged. It was also recalled that multiparametric dosimetry is required to guide medical treatment in case of accidental overexposures.

Calibration of dose response and characterization of the effective dose range of different dosimeters are required. The recommendation was made to appraise the ability of biological dosimetry to contribute to the evaluation of dose in the low dose range for risk analysis purposes. Intercomparison and networks for cooperation and assistance were requested.

Conclusions — Characterization of radiation exposure

While there continues to be much interest in both internal and external dosimetry, there were few radical new developments, which perhaps demonstrates

maturity in this area. Nevertheless, many interesting papers outlined recent progress and Ideas For The Future That Could Be Summarized As Follows:

- Use of voxel phantoms in external and internal dosimetry is increasing in importance and artificial neural networks and genetic neural networks are increasingly being developed for use in computations;
- Many national, regional and international intercomparisons covering all aspects of external and internal dosimetry for routine as well as accident situations, have identified lessons;
- There is an increasing need to improve understanding of uncertainties and limitations in dosimetry assessments, and for training in all aspects of dosimetry for a growing number of people;
- Overall, easy to understand, accurate and validated dosimetric methods and systems underpin rational decision making for radiation protection professionals, and in particular implementation of the ALARA principle;
- In biological dosimetry there is interest in developing a method for evaluating dose at low levels and developing intercomparison networks.

I.2. BIOLOGICAL EFFECTS OF RADIATION EXPOSURE

Under the motto "Towards global understanding on the effects attributable to radiation exposure", this scientific area covered the following topics:

- Effects on molecules, organelles and cells, with 38 papers;
- Effects on tissues and organs, with 29 papers;
- Radiopathology, with 11 papers;
- Radio-epidemiology, with 46 papers.

Apart from the topical sessions, there was also a Special Plenary Session on the NCRP's 44th Annual Meeting on low dose and low dose rate radiation effects and models (see above).

TS I.2.1. Effects on molecules, organelles and cells

The topics on Effects on Molecules, Organelles and Cells included:

- Progress in understanding molecular biology;
- Gene role and cell function (simple DNA damage vs. clastogenic effects);
- Efficiency of repair mechanisms;
- Influence of apoptosis;

- Effect of genomic instability;
- Impact of bystander effects and adaptive response;
- Individual radiosensitivity (genetic and epigenetic factors, mechanisms involved in radiation induced carcinogenesis, and effects on germ cells).

Important phenomena concerning radiation induced DNA lesions and repair mechanisms were presented. Damage to DNA can be detected after doses as low as 100 mGy in human cancer cells. Cytogenetic effects observed following exposure to low energy X rays (30 kV, such as that used for mammography) were found to be 1.5 greater than effects observed following exposure to120 kV photons. This was assumed to be related to the different energy deposition pattern following photoelectric interactions in the two radiation fields. New evidence on radiation induced deletions in mitochondrial DNA was discussed. Cell response to high LET charged particles (p or Li) was presented.

A presentation was given on the European integrated project NOTE, which involves 20 countries and is aimed at investigating the mechanisms of bystander effect, genomic instability and adaptive response and whether they could modulate cancer risk in the low dose range (protection or harmful effect?). The investigation also includes the role and relevance of these responses in non-cancer diseases and their possible implication in radioprotection, which could eventually contribute to new radiation biology paradigms.

Bystander effects, which are mostly observed at low dose and low dose rate, are an important issue in radiation protection. These effects raise the question of supra linearity, since more cells than directly hit cells are concerned. Conversely, low dose gamma rays seem to reduce spontaneous neoplastic transformation. Bystander effect was observed in human breast carcinoma cells cultured in irradiated conditioned medium (ICM) from similar cells exposed to 2 Gy 4 MV photons from a linear accelerator, thus suggesting this effect may be induced after exposure to radiation doses used in standard radiotherapy. However, it was recommended not to focus on one single mechanism but to have a broader view.

Peripheral lymphocytes in people living on the Techa riverside showed an increased frequency of dicentrics and higher level of apoptosis 59 years after onset of their chronic exposure. These results suggest the existence of genomic instability in members of this cohort.

Much new information was presented on the issue of gene influence on radiation sensitivity, which led to a lively discussion. The ongoing RISC-RAD European project on individual radiosensitivity was reviewed and highlighted. Gene influence on radiosensitivity was reported in several papers. A strain mouse exhibiting higher resistance to radiation could provide a useful experimental model for future investigation of the immune system's role in radiation resistance. It was reported that a transcription factor involved in DNA repair

(ATF3) is radiation induced in mammalian cells with a time and dose dependence requiring normal status of p53. The role of histamine, a growth factor for many neoplasms, in modulating the radiosensitivity of human malignancies was also presented.

Radiosensitivity was tested in patients using alkaline single cell microgel electrophoresis (comet assay), suggesting that this assay may have a good predictive potential for the detection of patients at a greater risk of developing adverse effects after radiotherapy.

Comet assay was also performed in children undergoing radiological medical procedures. The ratio of comet tail length before and after diagnostic exposure seems to correlate with dose.

Radioprotective effects of several compounds were explored in both normal and tumour cells, including carboxyfullerene derivative C3, dimethyl sulfoxide (DMSO), major heat shock proteins (Hsps) and organic compounds containing selenium. Their ability to attenuate radiation effect apoptosis and to modulate oxidative status acting as free radical scavengers was evaluated.

A stochastic model to simulate irradiations and predict carcinogenetic effects was presented, including the concept of 'breaking barrier cell mechanisms' (e.g. antioxidant defence, repair and apoptosis). A dose rate model has been applied to human fibroblasts and leukaemia cells and predicts that in the low dose range, biological response depends on dose rate rather than total dose.

TS I.2.2. Effects on tissues and organs and TS I.2.3 Radiopathology

The topics Effects on Tissues and Organs and Radiopathology were addressed in a combined topical session.

The topics on Effects on Tissues and Organs included:

- Health effects on tissues and organs;
- New information on cell killing 'deterministic' effects at high dose rate;
- Progress in understanding deterministic effects at low dose rate;
- Abscopal effects;
- Induced clastogenic plasma factors;
- Effects on the immune system;
- Hereditary effects (experimental data and epidemiological approach);
- Effects attributable to prenatal exposure (teratogenesis and mental retardation).

The topics on Radiopathology included:

- Acute radiation syndrome: pathogenesis, categorization, haematopoietic damage, gastrointestinal injury, neurovascular involvement, impact on other organs (e.g., lung, kidney) and multiorgan dysfunction/failure;
- Local radiation injury: pathogenesis, diagnosis, evaluation of the extension of injury (thermography, ultrasound, magnetic resonance imaging, etc.), dosimetric modelling, pharmacological and surgical treatment, novel therapeutic strategies including dose reconstruction guided surgery and mesenchymal stem cell therapy;
- Internal radionuclide contamination: diagnosis and assessment procedures, protocols for treatment, new decorporation agents;
- Management of combined injuries;
- Prevention and management of sequelae;
- Long term follow-up of radiation victims;
- Ongoing research in radiopathology.

The latest results of studies of radiation injuries on tissues and organs were reported. The classical description of stochastic effects on cells and deterministic effects on tissues was reviewed taking into account recent findings suggesting that threshold values for deterministic effects may be lower than previously thought. For cataracts the threshold seems to be lower by a factor 10. The threshold for cardiovascular injury appears to be 500 mGy, a much lower dose than initially implied by bomb survivor data. For teratogenesis, different thresholds in embryos and foetuses were reported. There seems to be no change in the paradigm for mental retardation, while for hereditary risk, there is a real decrease in previous estimations, which has led to a decrease in the tissue weighting factor for gonads from 0.25 to 0.04.

Impressive advances were reported in the treatment of radiation burns. A new approach, presented as a breakthrough, includes early treatment combining dose distribution reconstruction (with MRI + modelling) to guide surgical removal of tissue exposed to a dose over 20 Gy, followed by skin grafting, plastic surgery, and autologous mesenchymal stem cell (MSC) grafting. Spectacular results were reported following accidents involving workers in Chile and Senegal. There was an early disappearance of pain, optimal healing and excellent follow-up after 2 to 3 years. Ongoing clinical trials using MSC to treat haematological disorders after irradiation were also reported.

A regional medicodosimetric register was created in Siberia and it is studying workers exposed to long term occupational radiation in the low dose range. Preliminary conclusions show that there is an increased incidence of haemoblastosis and an increase in myocardial infarction. However, causality was

not unambiguously established. Another study reported effects of chronic contamination by ^{137}Cs in rats, including slight modifications of physiological systems without apparent development of pathologies.

TS I.2.4. Radioepidemiology

The topics on Radioepidemiology included:

- New epidemiological information ('life span study', Mayak-cohort studies, Chernobyl studies, occupational studies, patients studies, residential radon exposures);
- Molecular epidemiology;
- Uncertainties in epidemiological studies (bias, confounding factors, etc);
- Health risk estimates (attributability of cancer to radiation exposure, 'genetic' impact on populations, children, the unborn child, the frail and the elderly, and assessment of radiation detriment).

The keynote speech summarized the scientific basis for radiation protection. At this time there is a large amount of information arising from radioepidemiological studies, which complement animal experiments and mechanistic developments. Information sought in radioepidemiology includes:

- Cancer effects of low doses and dose rates;
- Effects of different types of radiation and of mixtures;
- Improved knowledge of effect modifiers (such as age, sex, environmental exposures, host factors (including genetic polymorphisms) and iodine deficiency);
- Cardiovascular and cognitive effects at low doses and dose rates.

New issues in molecular and cellular mechanisms addressed heretofore, such as genomic instability, adaptive response, bystander effects and DNA repairs are important, but their epidemiological significance is still unknown in humans.

Epidemiological assessments must be carefully designed to include all important variables such as age, sex, dose and dosimetric uncertainties, which are important risk factors for disease. Biological samples can be used to measure relevant genetic, epigenetic and other biological parameters.

Contributions to IRPA12 included many studies on health effects in populations exposed to low dose radiation, including cancer and non-cancer effects. Unsurprisingly, most epidemiological communications concentrated on workers' exposure: uranium miners, Mayak workers, and chemical, nuclear and

medical workers. Studies on Chernobyl exposures in cleanup workers and residents of contaminated areas were also presented. Other topics were related to better methods to assess exposure, biodosimetry to improve radiation epidemiology studies, new software, and epidemiological surveillances, such as the Belarusian Chernobyl Register and Canadian National Dose Registry of Radiation Workers. Some studies were related to radon, smoking and lung cancer.

The advantages and limits of epidemiology in radiation research and radiation protection were thoroughly reviewed, the major issue being to find evidence of a small risk at low doses of low LET radiation. More information will come as the study cohorts become older. In the future there needs to be closer collaboration between radioepidemiologists and radiation biologists.

A meta-analysis was reported of more than 40 articles and reports published since 1999 on cancer risk associated with alpha emitters of radon in miners. The findings include:

- Evidence of lung cancer excess;
- Compatibility with the linear non-threshold model;
- Radon lung cancer risk persists after taking into account smoking;
- There is a decrease of magnitude in risk with time since exposure;
- There is no inverse relationship between exposure and late effects at low doses;
- An excess of leukaemia is shown but causality could not be demonstrated.

Similar results were reported in three case control European studies.

A research overview was presented using the Canadian national dose registry of 600 000 radiation workers between 1951 and 2007 on cancer incidence and risk evaluation. Also reported was a study of occupationally exposed people at Mayak, in the Urals, covering 12 309 workers, exposed between 1948 and 1958, showing that they face an excess risk of leukaemia, lung, bone and liver cancers. French workers from Areva and EDF were reported to have a lower mortality than the French national population due to a healthy worker effect. It was also reported that medical workers in Canada present a 1.74 excess risk of thyroid cancer following a study of 67 562 workers between 1951 and 1987. Chinese medical workers present a 1.2 overall excess risk of cancers (skin, oesophagus and leukaemia in males, breast in females) following a study of 27 011 workers between 1950 and 1995 compared to controls.

As far as patient exposure is concerned, it was found that cardiovascular disease mortality following cancer in childhood is a long term risk after radiotherapy if heart and brain doses are higher than 5Gy. A risk related to chemotherapy was also observed.

The controversial issue of depleted uranium was also explored in some papers. However, a relationship to radiation dose from uranium was not demonstrated.

Biological indicators to support epidemiological studies were reported as well. Changes in homeostatic balance parameters were reported to be an indicator of prolonged exposure of medical workers in the low dose range. It was also found that occupational exposure to ionising radiation in the medical field does not induce an adaptive response. Chromosomal instability has been observed in interventional cardiology personnel in comparison to a normal group. Biological indicators of occupational radiation exposure were researched by looking for differences in the response of workers' lymphocytes to complementary irradiation; subsets of differentiation clusters may be useful indicators.

Post-Chernobyl related epidemiology was also high on the agenda. In Belarus, the state registry includes 276 000 people. Cohorts of people living in the evacuation zone and of people participating in liquidation are identified and form the basis for further prospective research. Dose distribution regarding thyroid disease indicates that 26% of the collective dose was received by 7% of the population in the most contaminated territories. A uniform Chernobyl registry for Russia and Belarus was created on the basis of medical and dosimetry data banks for further research on sub-registries of uniform population groups or diseases, e.g., thyroid cancers. In Moldova, a follow up study of 850 patients among 3500 Chernobyl liquidators seems to indicate some impairment of the immune system.

Epidemiological thyroid studies became particularly relevant after Chernobyl. Thyroid dose estimates are being improved for 2994 subjects exposed to nuclear testing fallout in Kazakhstan at Semipalatinsk between 1949–1962. Thyroid doses affecting 126 000 Belarusian citizens exposed after Chernobyl were reviewed and found to be reasonably consistent. It was validated that thyroid mass, one parameter of dose evaluation, correlates to body surface area: ultrasound measurements were performed on 12 000 controls. A new re-evaluation of thyroid cancer risk among Chernobyl liquidators was reported, as well as a re-evaluation of thyroid dose estimates in 12 000 Belarusians who were children in 1986. A report was presented on an ongoing meta-analysis of six studies regarding the risk of thyroid cancer following exposure to ^{131}I early in life. Significantly, it was reported that there is an excess risk of 4.5 for post-Chernobyl thyroid cancer morbidity in 65 575 children from Gomel and Bryansk.

An important aspect to take into account in epidemiological studies is the issue of probability vis-à-vis probability of effects at low radiation doses, a key issue for attributing effects to radiation exposure. This was also discussed at the congress.

Conclusions — Biological effects of radiation exposure

DNA lesions are of key importance to understanding the effects of ionizing radiation, and FISH and fluorescent antibody imaging are major cytogenetic techniques enabling visualization of these lesions, thus helping to increase knowledge. Non-targeted effects (i.e. DNA lesions that do not result from direct interaction with ionizing radiation), namely the bystander effect, the abscopal effect and genetic instability, were described in detail. The intrinsic mechanisms of these effects, which appear mostly at low doses and low dose rate must yet be characterized to help understand their importance for health effects.

DNA lesions are repaired through various mechanisms that operate more or less accurately depending on their nature (single strand breaks, double strand breaks, etc.), their number, and the rate at which they were produced. In this regard, humans are not identical and about 5% of the population is more sensitive, because DNA repair mechanisms and possibly other repair pathways are weak. These people may suffer from complications if exposed to ionizing radiation, e.g. tissue burns. The use of mesenchymal stem cells (MSCs) for the treatment of cutaneous burns resulting from accidental exposure to high doses has been a breakthrough in the last three years. In combination with early surgery guided by dosimetry, skin grafting — including millions of MSCs — provides fast pain relief and durable wound healing.

Since epidemiology is limited and unable to demonstrate a radiogenic effect such as cancer when background incidence is high, progress might increase through application of epidemiological techniques to cellular molecular signals. Thus collaboration between epidemiologists and radiation biologists should be encouraged.

Finally, it appears more clear that exposure to radon, long known as a carcinogenic agent, is the second cause of lung cancer after cigarette smoking. Therefore radiation protection authorities face the challenge of taking immediate action to reduce exposure to radon in buildings and private homes.

MAIN FIELD 2 — RADIATION PROTECTION PARADIGM: HARMONIZATION OF RECOMMENDATIONS

BACKGROUND PLENARY SESSION II

THE 2007 RECOMMENDATIONS OF THE ICRP. HOW HAVE THEY CHANGED, HOW CAN THEY BE APPLIED?

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Abstract

The basic recommendations of the International Commission on Radiological Protection (ICRP) are either restated or revised at intervals of about 15 years. The System of Protection outlined in its 1977 recommendations in Publication 26, developed in the 1990 recommendations in Publication 60, refined in the 2007 recommendations in Publication 103, comprises: (1) justification of the practice or intervention considered; (2) optimisation of protection, with source related dose and risk constraints to restrict optimisation options in order to increase equity and take account of multiple sources; and (3) the application of dose limits delineating what is never tolerable. ICRP stresses the importance of source related restrictions. For medical exposures, dose and risk limits and formal constraints are irrelevant; in this case Diagnostic Reference Levels serve a similar purpose. The 2007 recommendations put somewhat more emphasis on protection of the individual rather than protection of society emphasized in the 1990 recommendations. They aim at protection of non-human species as well as man, focus on the exposure situation (planned, existing, or emergency) rather than the process (practice or intervention), summarise and simplify advice given in various reports after Publication 60, and are formatted as concise recommendations underpinned by 'foundation documents' with more detail.

1. INTRODUCTION

The International Commission on Radiological Protection, ICRP, was established in 1928 by the International Society of Radiology (ISR) with the name 'International X ray and Radium Protection Committee'. In 1950, it was restructured to take into account uses of and exposures to radiation outside the medical area, and given its present name.

Its mission, according to its constitution, is to advance the science of radiological protection for the public benefit, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. The recommendations and guidance of the ICRP are published in the commission's journal, Annals of the ICRP.

2. HARMFUL EFFECTS OF IONIZING RADIATION

Through the genotoxic action of producing DNA mutations, radiation can cause cancer and genetic damage with a probability that depends on the dose. In addition, high doses can cause other immediate types of harm, which are inevitable if the dose is high enough to cause massive cell death. Thus, effects of ionizing radiation comprise: (1) 'deterministic' effects (such as severe burns) that occur with certainty after doses high enough to cause major cell death, and (2) 'stochastic' effects (such as cancer or hereditary effects), considered to occur with some probability more or less in proportion to dose at all dose levels.

The term 'deterministic effects' is not entirely adequate, and in Publication 103 (2007), ICRP points out that from a scientific standpoint, 'tissue reaction' would be more appropriate. However, current terminology is firmly established, and the two terms are used synonymously in the 2007 recommendations.

For stochastic effects, a linear, no-threshold dose response is considered to be the best currently available model of the true relationship (which is likely to be more complex).

In embryos and fetuses, a large fraction of cells are in cell division, which is the most radiosensitive stage, and organs are being formed, which means that thresholds for deterministic effects may be lower because fewer cells need to be killed in order to cause an effect. The observed level of developmental malformations after embryo/fetal irradiation is not very high. However, high fetal doses during formation of the cerebral frontal lobes are associated with a high frequency of mental retardation.

Recent research has revealed additional mechanisms by which radiation can cause cancer, e.g., induced genomic instability and bystander effects. These mechanisms, even if unknown at the time, will automatically have been included in past epidemiological estimates of radiation risk, so their discovery does not necessarily call for changes in radiological protection policy. However, understanding them is important in terms of treatment and curing radiation induced disease.

Recent observations in the cohort of Japanese atomic bomb survivors, the largest group providing epidemiological evidence on radiation induced disease, show that there are other radiation induced health effects (e.g. coronary heart disease). The body of evidence is not yet sufficient to provide a reliable numerical estimate of risk.

For members of the public, the 1990 recommendations in Publication 60 (ICRP, 1991) assessed the probability of fatal cancer due to radiation to be in the order of 5% per 1000 person mSv. In addition, ICRP suggested that non-fatal cancers and genetic disease should be taken into account in risk assessments. For

such diseases, severity is taken into account — it is regarded as less traumatic to survive a cancer than to die.

Any system of weighting for severity involves a subjective component. Using ICRP (1991) weighting, non-fatal cancers and genetic effects correspond to a further 2.3% deaths per person Sv, giving a total detriment from all cancers and genetic disease of 7.3 % per person Sv. For radiation workers, a somewhat smaller detriment coefficient of 5.6% is assumed (primarily because there are no children among workers).

These estimates were reconsidered in Publication 103 (ICRP, 2007). The risk of cancer induction is regarded as slightly higher than assumed in 1990, but the risk of hereditary disease is definitely smaller than assumed in 1990, and the calculation of detriment is now based on incidence rather than mortality. The total risk estimates are therefore about 10% smaller than they were in the 1990 Recommendations (see Table 1). The commission stresses, however, in Publication 103 that these numbers are very similar to those in the 1990 recommendations, and that for practical purposes it makes sense to continue to use 5% per Sv as an approximation of the risk for fatality. Therefore, the dose limits recommended by ICRP remain unchanged.

3. THE CONCEPT OF EFFECTIVE DOSE

Different kinds of radiation produce different amounts of damage for the same amount of energy deposited; different tissues differ in their radiosensitivity. The (doubly weighted) effective dose takes these differences into account. Table 2 and Figure 1 indicate radiation weighting factors used hitherto and included in the 2007 ICRP recommendations. Table 3 shows tissue weighting factors used in 1990 and in 2007.

TABLE 1. NOMINAL PROBABILITY COEFFICIENTS FOR STOCHASTIC EFFECTS (10-2 SV-1)

Exposed population	Lethality adjusted cancer risk	Lethality adjusted heritable effects	**Detriment**	Detriment Publ. 60
Whole population	5.5	0.2	**5.7**	7.3
Adult workers	4.1	0.1	**4.2**	5.6

TABLE 2. RADIATION WEIGHTING FACTORS, WR

Type and energy range	w_R
Photons	1
Electrons and muons	1
Protons	5 in Publ. 60, **2 in Publ. 103**
Alpha particles, fission fragments, heavy nuclei	20
Incident neutrons	**See Figure 1**

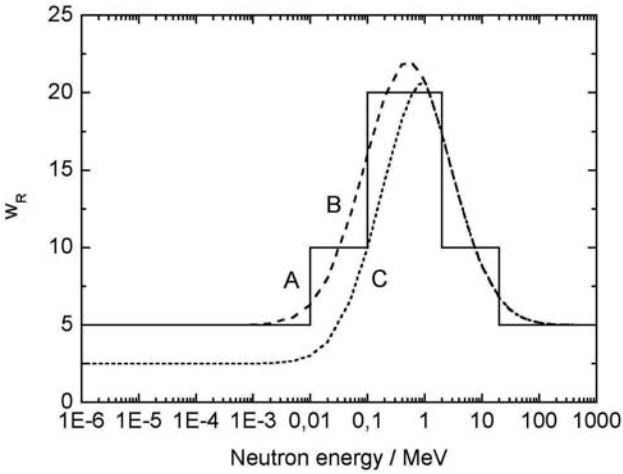

FIG.1. Radiation weighting factor, w_R, for incident neutrons vs neutron energy. (A) Step function and (B) continuous function used 1990, (C) function used 2007.

4. THE SYSTEM OF RADIOLOGICAL PROTECTION

The primary aim of the system is to provide an appropriate standard of protection for man without unduly limiting beneficial practices causing radiation exposure. In order to achieve this, the system is intended to prevent deterministic effects of ionizing radiation, and to minimise stochastic effects.

The system of radiation protection is concerned mainly with management of stochastic effects, as the total dose from all sources for most individuals is well below the level that might cause deterministic effects. In practice, radiation protection is concerned with the risks associated with a few mSv in a year, and the probability of harm is presumed to be proportional to the dose. Each source can

TABLE 3. TISSUE WEIGHTING FACTORS

Tissue	w_T	$\sum w_T$ 1990	$\sum w_T$ 2007
Gonads (1990)	0.20	0.20	—
Bone-marrow, breast, colon, lung, stomach, Remaining tissues (2007)*	0.12	0.48	0.72
Gonads (2007)	0.08	—	0.08
Bladder, breast, oesophagus, liver, thyroid (1990)	0.05	0.25	—
Bladder, oesophagus, liver, thyroid (2007)	0.04	—	0.16
Bone surface, skin, and (2007) brain, salivary glands	0.01	0.02	0.04
Remaining tissues (1990)*	0.05	0.05	—
Total	—	1.00	1.00

* Remaining tissues (10 in total in 1990, 14 in total in 2007)
In 1990: Adrenals, brain, upper large intestine, small intestine, kidney, muscle, pancreas, spleen, thymus, and uterus.
In 2007: Adrenals, extrathoracic (et) region, gall bladder, heart, kidney, lymphatic nodes, muscle, oral mucosa, pancreas, prostate, small intestine, spleen, thymus, and uterus/cervix.

be considered separately, and no single protective action can effect the total dose to an individual.

The ICRP recommendations can be applied to situations in which either the source of exposure or pathways leading to doses in individuals can be controlled. Individuals are exposed to both natural background radiation and to controllable sources. There are also sources for which the resulting effective doses are very low, or for which the combination of magnitude of dose and difficulty in applying control is such that ICRP will exclude them from its recommendations.

The three basic components of protection according to ICRP Publication 60:

A consequence of the linear, no-threshold dose response model is that no dose is regarded as completely safe. The associated risk may be small enough that it is not possible to demonstrate its existence statistically; it may be small enough that all concerned agree to disregard it from a practical point of view; but it is not zero. Therefore, dose limits cannot delineate dangerous from safe and are not efficient tools to minimise radiation risks. Instead, ICRP has devised a three tier system of radiation protection:

— *Justification of the practice or intervention at hand: No additional dose should be tolerated unless there is an associated benefit that outweighs the risk.*

The responsibility for justification of a practice usually falls on governments or governmental authorities (with radiological protection considerations one of several important inputs).

— *Optimisation of protection: Doses are to be kept as low as reasonably achievable; i.e. usually far below the dose limits.*

Both the individual dose and the number of exposed individuals should be kept as low as reasonably achievable, economic and social factors being taken into account. This should be constrained by restrictions on doses to individuals. Optimisation methods range from simple common sense to complex techniques of cost–benefit analysis or multiattribute analysis. The judgements involved are not purely quantitative and optimisation of protection should not be seen as cost–benefit analysis alone.

— *Application of dose limits: Dose limits separate what is always unacceptable from what could, under some circumstances, be tolerable.*

Dose limits must not be applied too rigidly in circumstances for which they were not designed (e.g., if doses in question are not controllable).

Medical exposures require separate guidance, because limitation of dose to the patient may reduce effectiveness of the diagnosis or treatment and is not recommended. Instead the emphasis is on justification of the medical procedure, and optimisation concentrates on the requirement to keep doses to patients as low as is consistent with the medical objectives.

Many additional aspects and complications should be considered. These include exposure conditions (practices adding radiation or intervention against pre-existing radiation), the source of exposure (public, occupational, medical), and the probability of incurring an exposure (near certain or potential). Limits cannot apply to interventions, and optimisation in an existing situation will not necessarily lead to the same dose levels as optimisation in a planned situation. Potential exposures need to be discussed for ‘normal’ accidents (often as a result of human factors), for operations over very long time frames (such as waste repositories), and for large disasters (such as major nuclear accidents).

The ethical basis for ICRP Recommendations: The principles of justification and optimisation aim at doing more good than harm and at maximising the margin of good over harm. Thus, they satisfy the conditions of utilitarian ethics, in that actions are judged by their consequences. The utilitarian approach is primarily a way of ensuring good conditions for the group concerned. However, even if average conditions for a group are satisfactory, risks could be unevenly distributed. The aim of dose limits is to ensure that no single individual is

exposed to undue harm. This is a case of deontological (duty) ethics, according to which some duties are imperative.

Dose constraints: In Publication 60 (ICRP, 1991), it was clarified that dose limits distinguish what is always unacceptable from what is sometimes, in view of the circumstances, tolerable. This led to an increased emphasis on dose constraints as a way to ensure a reasonably equitable distribution of doses when protection is optimised. In many circumstances, it is clear from the outset that no individual doses will come close to the dose limit under any reasonable circumstances. If this is the case, a more stringent restriction on optimisation, in the shape of a dose constraint, may be more relevant.

A dose constraint is a source related restriction, below the dose limit, on expected individual doses after optimisation. In practical terms, it is a restriction on the range of options that are considered in the procedure of optimisation. Since it is source related, it will often be set based on experience of similar well managed operations. In its capacity as a restriction on expected outcome, it is not a legal limit — in other words, if after optimisation individual doses turn out to exceed the dose constraint that was used, then reoptimisation may be required, but individual doses exceeding the constraint will not be in violation of any legal limit.

Dose constraints also serve another purpose; to take into account the presence of multiple sources. This may be particularly important in the context of public exposures. Earlier ICRP advice on generic dose constraints for public exposures remains valid.

The concept of source related dose and risk constraints has now been extended to all exposure situations: planned, emergency, and existing. The extended use of dose and risk constraints means that there is now more emphasis on deontological ethics, although all regulatory systems will include both kinds of ethics. These developments also mean the focus is no longer on the process (whether a radiological protection action is a ‘practice’ or an ‘intervention’), but on the exposure situation.

The Recommendations provide three bands of dose constraints: see Table 4. Specific constraints will be established at the national or local level by regulators or operators. Reference to the bands described in Table 4 will facilitate selection of appropriate constraints for specific situations that have not been explicitly addressed by ICRP. In planned situations, constraints will be lower than dose limits. In emergency situations and existing exposure situations, constraints will represent a level of dose/risk in which action is almost always warranted.

5. SPECIFIC ISSUES IN RADIOLOGICAL PROTECTION

Regulatory practices: ICRP continues to emphasize the benefits of regulations that encourage licensees to improve, rather than regulations which are too prescriptive and which transfer responsibility from licensees to regulators. Thus, in many occupational exposure contexts, licensees should select and set dose constraints. A 'safety culture' in which all employees feel a personal responsibility for safety and protection issues is highly desirable.

Earlier ICRP advice on generic risk constraints remains valid. An appropriate system for incident reporting and dissemination of knowledge is essential; in order for this to work as intended, the system must focus on learning from experience, not on punishment.

Medical exposures: The benefit of radiation as a tool in diagnostic examinations and radiotherapy is overwhelming, and in many countries, access to appropriate radiation methods needs to be increased significantly. However, there is also a potential for excess utilisation of radiation. This is aggravated in places which do not offer sufficient training in radiological protection. ICRP emphasises the need for appropriate criteria to avoid indiscriminate referrals of patients and accidental overexposure.

Protection of the environment: Hitherto, ICRP policy concerning protection of the environment has been anthropocentric: if humans are protected to the degree thought necessary, then other species are assumed to be adequately protected. Publication 103 states that protection of the environment should be considered in its own right. While the existing policy for protection of man may, as a side effect, actually provide sufficient protection for other species in most cases, ICRP needs a comprehensive system that should be in line with control of other pollutants; this should be transparent and have proper scientific references.

TABLE 4. BANDS OF DOSE CONSTRAINTS RECOMMENDED FOR WORKERS AND MEMBERS OF THE PUBLIC FROM SINGLE DOMINANT SOURCES FOR ALL TYPES OF EXPOSURE SITUATIONS THAT CAN BE CONTROLLED

Bands of projected effective dose (mSv per year)	Characteristics
20–100	Exceptional situations, e.g. emergency situations for workers (other than life saving or preventing catastrophic circumstances), and for public evacuation and relocation. Information, training, individual monitoring of workers, assessment of public doses. Benefit on a case by case basis. There is neither individual nor societal benefit from levels of individual exposure above this constraint.
1–20	For situations in which there is direct or indirect benefit for exposed individuals, who receive information and training, as well as monitoring or assessment. Applies to occupational exposure; for countermeasures such as sheltering, iodine prophylaxis in accidents, and for controllable existing exposures such as radon, as well as for caregivers of patients undergoing therapy with radionuclides.
<1	For situations with societal benefit, but without individual direct benefit; there is no information, no training, and no individual assessment for exposed individuals in normal situations. Some assessment of doses is performed to verify compliance.

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NON-IONIZING RADIATION PROTECTION STANDARDS: SIMILARITIES AND DIFFERENCES

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Abstract

With the development of new technologies and the increasing exposure of workers and the general public to a variety of sources, the need for protection against non-ionizing radiation (NIR) has emerged, and exposure standards have been developed. While taking into account the physical characteristics and specific interaction mechanisms of each kind of NIR (electromagnetic fields, optical radiation, ultrasound), protection systems show strong similarities with ionizing radiation (IR). This is partly due to historical reasons, since most of the pioneers of NIR protection were ionizing radiation experts, who transferred basic concepts of IR protection to NIR. The most important contribution is probably the creation of a two level protection system, based on primary and derived limits, though nowadays differently termed (basic restrictions and reference levels). On the other side, important differences exist, in particular related to the impossibility to define, both conceptually and in practice, a dose for most types of NIR. However, protection theory and practice in the two areas keep developing based to a large extent on a common philosophy, and a continuous exchange of ideas and experience should be maintained.

1. INTRODUCTION

The patrimony of knowledge, concepts and principles cumulated over more than one century in the field of ionizing radiation (IR) has greatly contributed to the growth of a culture of protection in a number of different areas. This is especially true for non-ionizing radiation (NIR), not only due to contiguity of the two areas, but also for historical reasons.

While sparse recommendations to limit workers' exposure to specific sources was already provided by individual scientists in the 1950s, the need for a systematic review of physical and biological NIR interactions, as well as possible health effects and related protection measures, was first recognized by IRPA, which had already created an *ad hoc* working group in 1973. The working group was the seed for the birth, in 1977, of the International Non Ionizing Radiation

Committee (INIRC) of IRPA. In 1992, IRPA/INIRC was dissolved and an independent body was simultaneously created — the International Commission on Non Ionizing Radiation Protection (ICNIRP).

Members of the original working group, and most of those of IRPA/INIRC, mainly had expertise in ionizing radiation and, not surprisingly, tried to adapt the system of protection developed for IR where possible to NIR. With the growing of research, however, the peculiarities of NIR, and also the differences among different kinds of NIR, became more and more evident, and new concepts and methods were developed.

In the course of more than half a century, NIR protection has evolved from sparse and rough recommendations to a comprehensive, complex and sophisticated system of protection. The basic approach to NIR protection is discussed in detail in an ICNIRP scientific document (ICNIRP 2002).

The NIR protection system is tailored to the specific characteristics and actions of non-ionizing radiation, however, similarities with IR remain, including some basic concepts and principles.

2. THE BASIC PRINCIPLES OF RADIATION PROTECTION

Similarities and differences can be discussed with reference to protection principles. It is well known that protection against ionizing radiation aspires to three basic principles, namely justification, optimization, and limitation. The fundamental question is whether, and to what extent, the same principles are suitable for non-ionizing radiation.

2.1. The principle of justification

Essentially, the principle states that the benefits of using radiation must outweigh the drawbacks. While rather obvious in definition, the principle raises questions and problems in practical application.

Justification is frequently invoked in medical practice, where radiation exposure is intentional. This is also the case for NIR, for example with the use of magnetic resonance imaging (MRI) for diagnostics, or radiofrequency and microwave heaters for diathermy, or UV therapy. In the case of diagnostic imaging, a balance of alternative techniques, based on either ionizing or non-ionizing radiation (MR, ultrasound) is often required.

The justification is more problematic for technologies and sources where the emission of radiation, and consequently human exposure, is non-intentional. In this case justification involves consideration of a number of other factors besides health risks. The problem exists to justify IR, e.g. nuclear power plants,

but NIR is more evident and widespread, especially in the case of electromagnetic fields. The existence of electric power lines, broadcasting towers and base stations for mobile telephony is obviously justified, given the outstanding benefits of energy and communication. What could be questioned are the characteristics and siting of a specific plant, or the number of plants required for good quality service. Such discussion involves social and economic considerations that may be more relevant than health risks which are hypothetical and, if they existent, very small.

2.2. The principle of optimization

The ALARA principle requires that exposures be maintained at the lowest level reasonably achievable, taking social and economic aspects into consideration. Optimization is achieved when the total of cost of protection measures (which increase with decreasing exposure) and the direct and indirect costs of health impacts reaches a minimum.

The process has been implemented for IR with difficulties and debates, but seems to not be applicable to NIR. The cost balance requires both curves to be quantitatively known, and that is not the case for electromagnetic fields either of low or high frequency.

ELF (extremely low frequency) magnetic fields, such as those generated by power lines, were classified by IARC as 'possibly carcinogenic in humans', based on some epidemiological evidence of association with childhood leukaemia. However, the exposure–response relationship is limited to a few points and affected by large error margins, thus preventing reliable extrapolation. For radiofrequency fields, on the other hand, there is no convincing evidence — from either epidemiological or biological studies — that they induce or promote cancer, or are associated with other long term effects.

It should also be noted that social costs, taking into account benefits of the technologies, are extremely variable between countries, and also between different social groups within the same country.

Based on these considerations, the application of the ALARA principle to non-ionizing radiation seems impossible.

2.3. The principle of limitation

Exposure limits have been established for all kinds of non-ionizing radiation. The systems of protection developed, however, are different depending on the type of NIR. ICNIRP recognizes that different protection systems exist depending on the nature of health effects and the relationship to exposure. If health effects are established, and their dependence assumes the shape of a

threshold, setting exposure limits below the threshold assures that effects are totally prevented. If effects are established, but do not exhibit a threshold (this is typically the case with long term effects), a system based on a level of acceptable risk is more appropriate. Finally, if risks have been hypothesized but not adequately proven, precautionary measures may be adopted.

In the case of electromagnetic fields, all scientifically established effects are acute, and exhibit definite thresholds. The effects can be described in terms of physical quantities internal to the body, which are related to biological responses more than intensity of the external field. The most relevant of these quantities are the induced electric field in the case of ELF, and the specific absorption rate (SAR) in the case of RF. For historical reasons shortly discussed below, these are usually called 'dosimetric quantities', though in most recent standards the more correct term 'biologically effective quantities' is used.

Thus, the principle of limitation is applicable to non-ionizing radiation, and protection standards have been developed with similarities to IR. However, relevant differences exist, in particular with regard to the concept of dose.

To better clarify, the main features of NIR protection standards and recommendations for EMF exposure are briefly discussed, with special reference to the ICNIRP standard (ICNIRP 1998). Other international and national regulations have been developed that, apart from some differences in numerical values of limits, are based on the same methodological approach, the same general scheme, and the same scientific database.

3. MAIN FEATURES OF EMF STANDARDS

ICNIRP standards are based on a two level scheme, showing evident analogies with ionizing radiation. So-called basic restrictions are defined which represent the true limits above which an individual should not be exposed. These limits are expressed in terms of relevant biologically effective quantities (e.g. in situ induced electric field, or SAR). Given the practical impossibility of directly measuring internal quantities, so-called reference levels are derived, in terms of more familiar physical quantities such as electric field strength, magnetic flux density, or power density.

Reference levels are environmental values of field intensity that, if not exceeded, guarantee compliance with basic restrictions. They are in fact derived assuming the best coupling between the external field and the human body. That implies that if reference levels are not exceeded, compliance with basic restrictions is assured, though the opposite is not true. If reference levels are exceeded, more in depth investigation is required to verify compliance with standards.

The two level system was derived looking at IR standards as a model, and similarities are evident. Other analogies exist, such as consideration of total body exposure and local exposure; the latter is of importance in the case of non-homogeneous electromagnetic fields, a situation that frequently occurs in workplaces, but which has assumed relevance for the public too with the spreading of mobile telephony and other EMF based technologies (Wi-Fi, Wi-Max, RFID, etc.).

4. THE CONCEPT OF DOSE

The process through which biologically effective quantities are derived from environmental levels of electromagnetic fields and radiation is called dosimetry. The name again suggests analogies with IR, and reflects the efforts made in early times by pioneering experts to define a dose for electromagnetic fields. However, the impossibility of defining an EMF dose is nowadays recognized, based both on experimental evidence and theoretical grounds.

A dose is, by definition, a measure of something imparted to an organism. It is useful to account for cumulative effects of prolonged exposure to (or assumption of) a given agent. In some circumstances, it may also account for the overall effect of different agents (e.g. different kinds of radiation).

In the case of electromagnetic fields, there is no evidence of cumulative effects due to chronic exposure, and therefore a dose would be of no use even when it can be conceptually defined, which is not always the case. The biologically effective quantity for RF fields, SAR, represents power absorbed per unit of time. For prolonged exposure, it could be integrated over the exposure time, given the total energy absorbed, i.e. a quantity with sound physical meaning, which could be reasonably associated to cumulative effects if they existed. In contrast, in the case of ELF fields, integration of the induced electric field would lead to a quantity with no physical meaning. Time consideration could make sense for hypothetical stochastic effects of low level exposure, but any shape of the relation would be arbitrary.

There is also no basis (with the exception of SAR) for combining contributions from fields of different frequency in the case of simultaneous exposure to different sources, or exposure to a multiple frequency source.

5. PROTECTION SYSTEMS IN THE CONTEXT OF PUBLIC DEBATE

The possible risk of long term EMF exposure has been the object of strong controversy for many years. ICNIRP guidelines, as well as other international

standards, have been criticized as inadequate, and the adoption of more stringent restrictions has been advocated based on arguments that often indicate ignorance or misconception of protection standards in general, and NIR standards in particular. It is therefore important to stress some fundamental features of the ICNIRP guidelines.

ICNIRP's recommendations are based on solid science, and on confirmed evidence. Only effects that are established based on commonly accepted scientific criteria are considered for setting exposure limits.

The guidelines are conservative. The critical effect, i.e. the effect that occurs at the lowest exposure level, is assumed to be the reference for setting basic restrictions. Preventing the critical effect ensures prevention of any other health effect. In addition, reduction factors are introduced, leading to basic restrictions much lower than the threshold for effects. Finally, the assumption of worst case conditions in the derivation of reference levels implicitly introduces additional reduction margins.

A misunderstanding seems to exist between basic restrictions and reference levels, which are considered to be two equivalent sets of limits (in effect, the terms 'primary limits' and 'derived limits' were initially used). Consequently, environmental field levels are often considered the measuring stick for biological and health effects, rather than individual exposure measured by biologically effective quantities.

Such misconceptions may lead to negative and paradoxical consequences, in particular when precautionary measures are adopted. A significant example is the attitude towards locating base stations for mobile telephony in a way that minimizes the environmental electric field, rather than optimizing communication. As the consequence, the power emitted by phones, the contribution to user SAR of which is orders of magnitude higher than base stations, increases, with a dramatic increase in total exposure (and even more local exposure to the head).

6. CONCLUSIONS

Over the years, NIR standards have evolved from simple and limited recommendations to become a complex and sophisticated protection system which is continuously refined and updated based on advances in research and taking into account the specific peculiarities of non-ionizing radiation.

However, much of the basic approach and the fundamental concepts remain the same for IR and NIR protection, and this common patrimony should be preserved and exploited. While it would be utopian and misleading to talk about a unique radiation protection, it is important that mutual attention be paid to future developments of either discipline.

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THE INTERNATIONAL COMMISSION ON RADIATION UNITS AND MEASUREMENTS: PAST AND CURRENT ACTIVITIES

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Abstract

The International Commission on Radiation Units and Measurements (ICRU) was founded in 1925 with the goal of identifying a unit for the specification of medical X ray exposures. Since its inception, the role of ICRU has expanded and it is now seen as providing definitive guidance on concepts, quantities and units involved in the measurement and uses of ionizing radiation in medical, industrial and scientific applications, In collaboration with the International Commission on Radiation Protection (ICRP), the ICRU also plays a major role in providing guidance with respect to protection from the harmful effects of ionizing radiation. The paper that follows attempts to provide a brief overview of the efforts of the ICRU with respect to the measurement and various uses of ionizing radiation as well protection from its possible harmful effects. Guidance is provided to in order to access appropriate ICRU reports as sources of further information.

1. MAIN GOALS AND ACHIEVEMENTS OF ICRU

In the 1920s, physicians and physicists working with ionizing radiation identified the need to establish an internationally accepted 'X ray unit'. For that reason, the International Congress of Radiology created the ICRU in 1925 (originally named International X-Ray Unit Committee) with the mandate to define such a unit. In 1928, a first definition of the unit röntgen was proposed by the ICRU. The need for radiation units originated from medical radiation applications. However it was soon recognized that there was a need in other areas of ionizing radiation applications, including the field of radiation protection, to establish definitions for quantities and units, to develop concepts, and to provide guidance on radiation measurement techniques. ICRU activities expanded considerably with the growing applications of ionizing radiation. From its beginning, the ICRU aimed at developing a coherent system of quantities and units for ionizing radiation based on scientific rigor and consensus in order to enable all users of ionizing radiation to communicate and interpret results in an

unambiguous and harmonized way. Many of these quantities and units are rigorously described and defined in Report 60, Fundamental Quantities and Units for Ionizing Radiation, issued in 1998 and a revision which will appear in the near future.

Today's ICRU mission statement is:

> "To develop and promulgate internationally accepted recommendations on radiation related quantities and units, terminology, measurement procedures, and reference data for the safe and efficient application of ionizing radiation to medical diagnosis and therapy, radiation science and technology, and radiation protection of individuals and populations."

The framework of ICRU activities includes the following categories:

- A clear evaluation of concepts;
- Accurate and scientifically rigorous definitions of radiation quantities and units;
- Specification of the domains or limits for which and within which quantities are defined;
- Protocols for reporting radiation therapy;
- Measurement methods and related physical reference data.

Harmonization of language and concepts, and reporting accuracy has always been one of the major goals of the ICRU. Indeed, agreement on terminology, concepts, quantities and units is a prerequisite for a fruitful exchange of information and comparison of results among different disciplines, scientific and medical centres, and different countries.

The general goals of the ICRU are achieved with the help of selected groups of volunteer international experts in different fields in which ionizing radiation is involved, mainly:

- Radiation physics;
- Radiation therapy;
- Medical imaging;
- Radiation protection;
- Non-medical applications.

Below is a brief summary of recent ICRU activities in the areas listed above, together with references to some pertinent reports. A complete listing of all ICRU reports can be found at http://www.icru.org

2. RADIATION THERAPY

The ICRU has published a series of reports on underlying physics, concepts and quantities for applications in radiation therapy, especially where novel techniques are involved [see ICRU Report 50, 1993; ICRU Report 64, 2001; ICRU Report 71, 2004; ICRU Report 72, 2004, and ICRU Report 78, 2007]. In addition to the development of dose measurement techniques, it is important in medical applications to specify where the dose is prescribed and delivered.

In recent years, ICRU has spearheaded a trend to replace reference points by reference volumes for which absorbed dose is prescribed and reported. This shift towards volume concepts is made possible because of striking developments in medical imaging coupled with the availability of more powerful 3-dimensional dose computation. As far as volumes related to 'tumours' and 'organs at risk', the ICRU has defined a series of universally accepted volumes for reporting:

- Gross Tumour Volume (GTV) which corresponds to the clinically visible and measurable tumour mass;
- Clinical Target Volume (CTV) which includes a safety margin for sub-clinical involvement;
- Planning Target Volume (PTV) which takes into account uncertainties in patient beam positioning;
- Organs at Risk which accounts for any organ likely to undergo significant radiation damage;
- Planning Organ at Risk Volumes which takes into account uncertainties in the position of the Organ at Risk.

3. MEDICAL IMAGING

Because radiological imaging has potential both to significantly benefit patients and induce cancer, the radiological community and the ICRU have major interests in developing and promulgating approaches to achieving the required clinical information from diagnostic procedures with minimal exposure to the patient. To this end, ICRU has produced a number of reports. These reports have covered areas such as modulation transfer functions [ICRU Report 41, 1986], development of diagnostic phantoms [ICRU Report 48, 1993], assessment of image quality [ICRU Report 54, 1995], absorbed dose specification in nuclear medicine [ICRU Report 67, 2002], assessment and improvement of image quality in chest radiography [ICRU Report 70, 2003], analysis of accuracy in medical imaging [ICRU Report 79, 2008], bone densitometry [ICRU Report 81, 2009] and mammography [soon to be published as ICRU Report 82 (2009)].

While not normally considered an imaging procedure, utilizing ionizing radiation to determine bone densitometry has become one of the major uses of radiation in medicine. The ICRU has published a report related to dosimetry in general X ray procedures [ICRU Report 74, 2005] and will soon publish another with specific reference to computed tomography (CT).

4. RADIATION PROTECTION

The ICRU has since its inception in 1925 maintained major involvement in the development of concepts, quantities, units and measurement procedures related to radiation protection, both on its own and in collaboration with the International Commission on Radiological Protection (ICRP).

Introduction of the quantity dose equivalent in 1962 as a product of absorbed dose and the LET dependent quality factor was a significant step in the context of radiation exposure limitation because it accounted for differences in the biological effectiveness of different radiation types. In 1977 [ICRP Report 26], the ICRP introduced a system of dose limitation that included the quantity effective dose equivalent as a weighted sum of the dose equivalent in different organs. In 1985, ICRU introduced [ICRU Report 39] operational quantities for individual and ambient monitoring of external radiation. These quantities can be determined experimentally and provide an adequate approximation for effective dose equivalent and its successor effective dose. This was followed by practical guidance for the determination of operational quantities for external photon (and electron) radiations in two reports [ICRU Report 43, 1988; ICRU Report 47, 1992]. A similar report for external neutrons was published in ICRU Report 66 [2001].

A summary report, ICRU Report 51 on Quantities and Units in Radiation Protection Dosimetry was published 1993.

Together with the ICRP, a report was prepared called Conversion Coefficients for Use in Radiological Protection against External Radiation [ICRU Report 57, 1998] which is of great practical importance in operational radiation protection.

The ICRU has also provided practical guidance for radiation protection measurements in a number of reports. These cover a variety of areas including Gamma Ray Spectrometry in the Environment [ICRU Report 53, 1994], Dosimetry of External Beta Rays for Radiation Protection [ICRU Report 56, 1997], Quantities, Units and Terms in Radioecology [ICRU Report 65, 2001], Retrospective Assessment of Exposure to Ionizing Radiation [ICRU Report 68, 2002], Direct Determination of Body Content of Radionuclides [ICRU Report 69, 2003] and Sampling for Radionuclides in the Environment [ICRU Report 75, 2006].

An ICRU committee is working on approaches to the dosimetry of low dose exposures to ionizing radiation which addresses the problems of dosimetry for non-homogeneous dose distributions in cells, tissues and organs. The outcome of the work of this group could have an impact on radiation protection at low doses and low dose rates.

Currently the ICRU and the ICRP are collaborating on the preparation of several joint reports. A report on adult male and female ICRP–ICRU reference phantoms, based on whole body medical imaging of patients, is set to appear soon. These so called voxel phantoms, are consistent with reference data given in ICRP Publication 89 [2002], Basic Anatomical and Physiological Data for Use in Radiological Protection: Reference Values. The phantoms will be used to provide reference dose conversion coefficients for the determination of effective dose and organ doses for external radiation. These conversion coefficients will be published jointly by ICRP and ICRU.

A joint ICRU/ICRP report on doses from cosmic ray exposure for aircrews is nearly complete.

5. NON-MEDICAL APPLICATIONS

While ICRU's original mandate was to deal with medical uses of ionizing radiation, it has over the years made significant contributions to other areas of radiation science and application including radiation in the environment [ICRU Report 65, 2002 and Report 75, 2006], industrial processing [ICRU Report 80, 2008] and quality assurance in standards laboratories [Report 76, 2006].

ICRU has also published several reports on compiled and evaluated basic physical data such as Average Energy Required to Produce an Ion Pair [ICRU Report 31, 1979], Stopping Powers for Electrons and Positrons [ICRU Report 37, 1984], Photon, Electron, Proton and Neutron Interaction Data for Body Tissues [ICRU Report 46, 1992], Stopping Powers and Ranges for Protons and Alpha Particles [ICRU Report 49, 1993], Secondary Electron Spectra from Charged Particle Interactions [ICRU Report 55, 1995], Nuclear Data for Neutron and Proton Radiotherapy and for Radiation Protection [ICRU Report 63, 2000], Stopping of Ions Heavier Than Helium [ICRU Report 73, 2005], and Elastic Scattering of Electrons and Positrons [ICRU Report 77, 2007].

These data are of importance in the areas of radiation science and radiation measurements.

6. FINAL REMARKS

The ICRU has, since its creation in 1928, played an important and internationally accepted role in the definition of quantities and units and for measurements in all areas in which ionizing radiation is applied. These efforts have contributed significantly to a scientifically rigorous system of quantities and a worldwide harmonization of radiation metrology, in particular in radiation therapy. A committee specifically dedicated to fundamental quantities and unit regularly reviews needs in this area and keeps close contact to the international community on physical units.

The ICRU continues to accept new challenges such as the development of concepts for novel radiation therapy modalities, for example to account for differences in biological effectiveness of different dose rates or fractionations and for different types of particles, such as the use of ^{12}C-ions for tumour therapy or the dosimetry of small radiation fields used in modern therapy.

ICRU continues to play an active role in all metrological areas of radiation protection. Collaboration with the ICRP in areas of common interest and competence has proven to be very fruitful and will most likely be continued.

SPECIAL PLENARY SESSION

THE INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION 80TH ANNIVERSARY: EVOLUTION OF ITS POLICIES THROUGH 80 YEARS

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Abstract

Within 12 months of the discovery of X rays in 1895, papers appeared in literature reporting adverse effects from high exposure. In 1925, the first International Congress of Radiology, held in London, considered the need for a protection committee, which it established at its second Congress in Stockholm in 1928. This paper celebrates the 80th anniversary of ICRP by tracing the history of its policy development and identifying some of the personalities involved from its inception up to the modern era. The paper follows its progress, from early controls on worker doses to avoid deterministic effects, through the identification of stochastic effects, to concerns about public exposure and increasing stochastic risk estimates. Key features of the recommendations made by ICRP from 1928 up to the most recent ones in 2007 are identified.

1. INTRODUCTION

This paper is based on 'A History of the International Commission on Radiological Protection' published by Clarke and Valentin [1] and also draws extensively from Lindell's 'The History of Radiation Protection' [2].

Röntgen discovered rX rays in 1895[3], and within a few months X ray dermatitis of the hands was observed in the USA by Grubbé [4], while in the UK Drury [5] described radiation damage to the skin of the hands and fingers of early experimental investigators. In December 1896, the American Wolfram Fuchs, an electrical engineer involved with X ray equipment [6], gave what is generally recognized as the first protection advice. This was:

> "make the exposure as short as possible, do not stand within 12 inches (30cm) of the X ray tube, and coat the skin with Vaseline and leave an extra layer on the area most exposed."

In the next ten years, many papers were published on the tissue damage caused by radiation. However, during the first two decades following the discovery of X rays and radium, ignorance of the risks caused numerous injuries. X rays were used by military field hospitals as early as 1897, although the number of X ray injuries escalated during the First World War when primitive mobile X ray equipment was used in the field. In the early 1920s radiation protection regulations were prepared in several countries, but it was not until 1925 that the International Congress of Radiology (ICR) was formed and first met in London, to consider establishing protection standards.

The time was ripe for international cooperation. At that time, the most pressing issue was that of quantifying measurements of radiation, and the International Commission on Radiation Units and Measurements (ICRU) was created. The need for an international radiological protection committee was discussed and the task was to ensure that a number of physicists interested in radiation protection would be present at the next ICR. The second ICR was held in Stockholm in 1928 and ICRU proposed the adoption of the röntgen unit, an event which was noted with far more interest than the birth of what is now ICRP under the name of the International X Ray and Radium Protection Committee (IXRPC). As a courtesy to the host country, Swedish medical physicist Rolf Sievert (at the age of 32) was named chairman of the new committee; other members present included the engineer turned physicist Lauriston Taylor from US National Bureau of Standards and medical physicist Val Mayneord from the UK, both of who were in their 20s at the time. There were only two medical doctors on the committee [2].

ICRP remains one of three commissions of the International Society for Radiology, the others being ICRU and the International Commission for Radiologic Education (ICRE); the parent body approves the rules by which the commissions operate. As with the other commissions, ICRP members are elected on merit and not by governmental nomination.

2. EARLY RECOMMENDATIONS

The early recommendations of IXRPC were concerned with avoiding threshold (deterministic) effects, initially in a qualitative manner. The committee issued its first recommendations, consisting of 41 paragraphs, in three and a half pages of recommendations on protection against X rays and radium. Their approval was confirmed by the ICR General Assembly on 27th July 1928.

The first recommendations in1928 [7] noted that:

> "The effects to be guarded against are injuries to superficial tissues, derangements of internal organs and changes in the blood."

As a remedy, a prolonged vacation and limitation of working hours were recommended. The main emphasis was of a technical nature on shielding requirements and included no dose limits. However, paragraphs (10) and (11) gave some guidance on protection,

> "(10) An X ray operator should on no account expose himself unnecessarily to a direct beam of X rays.
> (11) An operator should place himself as remote as practicable from the X ray tube. It should not be possible for a well rested eye of normal acuity to detect in the dark appreciable fluorescence of a screen placed in the permanent position of the operator."

Before the Second World War, the protection committee met at each of the international Congresses, in 1931, 1934, and 1937. Following the 1934 meeting, the Committee renamed itself a Commission and recommendations were published that included a 'dose limit' for the first time in terms of a 'tolerance dose', implying the concept of a safe threshold [8]:

> "Under satisfactory working conditions a person in normal health can tolerate exposure to X rays to an extent of about 0.2 röntgens per day."

This would be about twenty-five times the present annual dose limit for occupational exposure, 20 mSv per year, and about ten times the limit in a year (50 mSv).

After WWII, the only two survivors of the Commission were Taylor and Sievert. The first post war ICR was held in 1950 and the Commission meeting resulted in an eight page report, printed in the British Journal of Radiology in 1951 [9]. The Commission now recommended a maximum permissible dose of 0.5 röntgen in any one week in the case of whole body exposure to x and gamma radiation (at the surface, corresponding to 0.3 röntgen in 'free air'), and 1.5 röntgen in any one week in the case of exposure of hands and forearms. The previous limit of 1 röntgen per week (0.2 röntgen per day) was considered too close to the probable threshold for adverse effects.

The 1951 report of the Commission was quite comprehensive. There was a table of RBE-values and data on a Standard Man. Maximum permissible body burdens were given for eleven nuclides, including radium-226. It was recognized

that in the case of uranium it is the chemical toxicity and not radioactivity that is limiting. In these 1950 Recommendations, the Commission provided an impressive list of health effects that should be kept under review:

— Superficial injuries;
— General effects on the body, particularly blood and blood forming organs, e.g., production of anaemia and leukaemia;
— The induction of malignant tumours;
— Other deleterious effects including cataract (and other less likely examples);
— Genetic effects.

It also proposed the establishment of five committees:

— I permissible dose from external radiation;
— II permissible dose from internal radiation;
— III protection against x beta and gamma rays from sealed sources;
— IV protection against electromagnetic radiation above 3MeV, electrons neutrons and protons;
— V disposal of radioactive waste and handling of radioisotopes.

In summary, for the first 60 years after the discovery of ionizing radiation, the ethical position was simply that of avoiding deterministic effects from occupational exposures and the principle of radiological protection applied in order to achieve that was to keep individuals below relevant thresholds. Low doses of radiation were deemed beneficial, largely because radiation was used for medical purposes, and radioactive consumer products abounded.

3. THE NEED FOR CHANGE

In the mid 1950s there was growing public concern about radiation risks because of extensive nuclear weapons testing and this development was also of concern for ICRP. The Commission recognized the need to protect the general public in the face of increasing use of radioactive sources and with nuclear energy expected to be an expanding industry. The major problem, based on experimental data, was believed to be hereditary harm but the awareness of leukaemia among radiologists, and information about an increased leukaemia frequency among the survivors of Hiroshima and Nagasaki also contributed to a decision to be cautious with regard to public exposures.

The next ICRP meeting was at the 7th ICR in Copenhagen in 1953. Recommendations from the meeting were published in 1955, again in the British Journal of Radiology [10]. In that publication the Commission's own recommendations were presented together with reports from the Committees. The basic principle was stated emphatically:

> "In view of the incomplete evidence on which the (risk) values are based coupled with the knowledge that some effects are irreversible and cumulative…it is strongly recommended that every effort be made to reduce exposure to all types of ionizing radiation to the lowest possible level."

The report of Committee I concluded that 'no radiation level higher than the natural background can be regarded as absolutely 'safe'' and that the problem therefore was to 'choose a practical level that, in the light of present knowledge, involves a negligible risk', and 'Maximum permissible doses should be set so as to involve a risk which is small compared with other hazards in life.' It was recommended that individuals outside of controlled areas should not receive more than 1/10 of the occupational dose limit. Considering the genetic risk to entire populations, the Commission wanted a temporary limitation of population exposures to 'an amount in the order of the natural background in presently inhabited regions of the earth'. However, at this time the Commission had not rejected the possibility of a threshold for stochastic effects.

The concept of critical organ was now introduced, and the recommended dose limit was related to the organs that were said to be critical in the case of whole body exposure, i.e., the gonads and the blood forming organs. The limit, expressed in the new unit, was given as 0.3 rem per week. Committee II, chaired by Karl Z. Morgan (legendary health physicist at the Oak Ridge National Laboratory in Tennessee) made a report which included tables on maximum permissible concentrations in air and water for occupational exposure to some ninety radionuclides. These MPC-values were all based on a weekly dose of 0.3 rem to the organ that was critical in each case.

4. THE BEGINNINGS OF THE MODERN ERA

In 1957 there was pressure on ICRP from both WHO and UNSCEAR to reveal the decisions of its 1956 meeting held in Geneva, the first to be held away from the ICR, which was in Mexico City. The final document, adopted in September 1958 and published in 1959, contained the Commission's Recommendations. This was the first ICRP report published by Pergamon Press, and

although it had no number it is usually referred to as ICRP Publication 1 [11]. The document began with a 'Prefatory Review' and it was the first time the basis of the Commission's policy was presented and discussed. The principles from 1956 were developed into a set of 87 paragraphs. The weekly dose limit of 0.3 rem was replaced by a limit of the accumulated dose equivalent, 5(N-18), corresponding to an average annual dose of 5 rem (50 mSv). For individual members of the public, the dose limit was set at 0.5 rem per year and, in addition, a genetic dose limit of 5 rem per generation was suggested together with a long and detailed 'illustrative apportionment'.

At that time, the Commission's basic policy was mainly determined by Committee I. Soon afterwards (in 1960), Karl Morgan had the Report of Committee II (ICRP Publication 2) ready for publication as a major document on internal emitters and with comprehensive tables on maximum permissible body burdens and MPC values. The same year, Committee III published its report (ICRP Publication 3) on protection from x rays and beta and gamma rays from sealed sources. The three documents, Publications 1-3, together definitely established ICRP as the leading international radiation protection authority.

The Commission also decided to reorganize the committee system and replaced the five 'Roman number' committees with four committees marked using 'Arabic numbers'; essentially the same as the present committees 1–4. The regulatory implications of the Commission's scientific conclusions were considered through Committee 4, which was created to look at the applicability of the Commission's Recommendations. Henri Jammet, a French radiopathologist, and Swedish physicist Bo Lindell were elected to the Commission and Jammet was chosen to chair the new Committee 4 to which, among others, Dan Beninson from Argentina and UK physicist John Dunster were elected. Beninson was originally a medical doctor but is known for his life long work in the physics of radiological protection.

The significance of stochastic effects more and more began to influence policy. It was soon time for more substantial revisions, and a new editorial group was appointed, chaired by British radiologist Edward (Bill) Pochin. The group drafted a document that was adopted by the Commission in September 1965 and published as ICRP Publication 9 [12]. During the drafting of ICRP Publication 9, the editorial group had been concerned about the many different opinions regarding the risk of stochastic effects. The Commission therefore asked a working group 'to consider the extent to which the magnitude of somatic and genetic risks associated with exposure to radiation can be evaluated'. The report of the group was published as ICRP Publication 8 in 1966 [13]. This was an important document because for the first time in ICRP publications, it summarized current knowledge about radiation risks, both somatic and genetic. The probability of leukaemia after an absorbed dose of 1 rad of gamma radiation

(i.e. 10 mGy) was estimated at 20 cases per million exposed. At the time it was assumed that the probability of all other types of cancer together was about the same as the probability of leukaemia, an assumption shown in time to have been an underestimate.

There was then a prolonged debate about how to deal with risk acceptability. In Publication 1, the 1955 words 'lowest possible' were succeeded by 'as low as practicable.' In the new Publication 9, the usual cautious warning (in paragraph 52) read:

> "As any exposure may involve some degree of risk, the Commission recommends that any unnecessary exposure be avoided and that all doses be kept as low as is readily achievable, economic and social consequences being taken into account."

Other considerations, e.g., taking into account more complex ethical issues, were not excluded by this wording, but the Commission considered them to be included in the adjective 'social'. There was as yet no guidance on how this recommendation should be applied. However, the Commission was increasingly doubtful about the existence of a threshold dose for cancer induction. Paragraph 7 read:

> "... the Commission sees no practical alternative, for the purposes of radiological protection, to assuming a linear relationship between dose and effect, and that doses act cumulatively. The Commission is aware that the assumptions of no threshold and of complete additivity of all doses may be incorrect, but is satisfied that they are unlikely to lead to the underestimation of risks."

Now there were stochastic effects, for which the probability of the effect, not its severity, is proportional to the size of the dose; the threshold was rejected. The problem had become one of limiting the probability of harm and much of what has subsequently developed is related to estimating that probability of harm and the deciding what level of implied risk is acceptable, tolerable, or, more importantly, unacceptable. Starting in the mid-1960s the main field of interest was the expanding nuclear industry. Protection philosophy was definitely shaped by the assumption of a linear dose response relationship without any threshold dose.

ICRP Publication 9 substantially renewed radiation protection philosophy by moving from deterministic to stochastic effects. It made a distinction between 'normal operations' and accidents where exposure 'can be limited in amount only, if at all, by remedial action'. The age prorated formula was abandoned and

the MPD for gonads and blood forming organs was now expressed as an annual dose of 5 rem (i.e. 50 mSv). The term ‘dose limit’ was introduced for the annual limit of 0.5 rem recommended for public exposure.

Paragraph 52 in ICRP Publication 9, which recommends that ‘all doses be kept as low as is readily achievable, economic and social consequences being taken into account’ called for further guidance. ICRP therefore appointed a task group to give advice. The group found that the optimum level of protection might be found by means of differential cost benefit analysis and that the principle described in paragraph 52 was the principle of protection optimization. The group’s report was published as ICRP Publication 22 in 1973 [14].

At that time, ICRP had a new editorial group working on a revision of Publication 9, which had proposed some rather radical changes. The concept of ‘critical organ’ was abandoned. It was now felt that there was sufficient knowledge of cancer risk for a number of organs to permit the calculation of a weighted whole body dose. A quantity based on such weighting had already been suggested in a paper by Wolfgang Jacobi, but in the new Recommendations the Commission only introduced the weighting procedure without presenting the result as a new quantity. This was first made in a statement in 1978, when the name ‘effective dose equivalent’ was introduced, following a proposal by German radiation physicist Wolfgang Jacobi.

5. THE 1977 RECOMMENDATIONS

The Commission first quantified the risks of stochastic effects of radiation in 1977, and proposed a System of Dose Limitation [15]. The Commission stated in paragraph 6 that:

> “Radiation protection is concerned with the protection of individuals, their progeny and mankind as a whole, while still allowing necessary activities from which radiation exposure might result.”

The Commission then went on to say in paragraph 14 that:

> “Although the principal objective of radiation protection is the achievement and maintenance of appropriately safe conditions for activities involving human exposure, the level of safety required for the protection of all human individuals is thought likely to protect other species, although not necessarily individual members of those species. The commission therefore believes that if man is adequately protected then other living things are also likely to be sufficiently protected.”

This was the first occasion during which ICRP addressed the question of radiation effects on species other than mankind, although clearly it was not pursued. Much ICRP work concentrated on the development of human biokinetic data and the assessment of doses both for workers and the public from the ranges of radionuclides likely to be encountered. This included the development of a 'Reference Man' to develop standardized dose intake data.

The 1977 Recommendations set out the new system of dose limitation and introduced the three principles of protection in paragraph 12:

> "No practice shall be adopted unless its introduction produces a positive net benefit;
> All exposures shall be kept as low as reasonably achievable, economic and social factors being taken into account; and
> The doses to individuals shall not exceed the limits recommended for the appropriate circumstances by the Commission."

These principles have since become known as **Justification**, **Optimization (ALARA)** and **Dose Limits**. The new principle of optimization was to generate much important work for ICRP as well as other national and international bodies. The principle was introduced because of the need to find some way of balancing the costs and benefits of introducing a source involving ionizing radiation or radionuclides. This process was not necessarily sufficient to protect individuals, so it was complemented by dose limits for individuals which were not to be exceeded. As a result of introducing this requirement, doses to non-human species were certainly reduced to some extent in the majority of situations.

The Recommendations were very concerned with the basis for deciding what is reasonably achievable in dose reduction. The principle of justification aims at doing more good than harm and that of optimization at maximizing the margin of good over harm for society as a whole. They therefore satisfy the 'utilitarian principle' of ethics, whereby actions are judged by their overall consequences, usually by comparing in monetary terms the relevant benefits (e.g., statistical estimates of lives saved) obtained by a particular protective measure with the net cost of introducing that measure. Paragraph 72 of Publication 26 suggests that the definition of ALARA depends on the answer to the following question:

> "Is the collective dose sufficiently low that further reduction in dose would not justify the incremental cost required to accomplish it?"

Paragraph 75 then recommended the use of differential cost–benefit analysis where the independent variable is the collective dose and further

recommended that a monetary value be assigned to a unit of collective dose. This classical use of cost–benefit analysis addresses the question: 'How much does it cost and how many lives are saved?' However, this approach does not allow for the protection of the individual from the source, so ICRP retained the concept of a dose limit to protect the individual from all controllable sources.

The concept of collective dose was originally introduced for two reasons; the first to facilitate cost–benefit analysis, and the second to restrict the uncontrolled build-up of exposure to long lived radionuclides in the environment. This was because a global expansion of nuclear power reactors and reprocessing facilities was foreseen, and there were fears that global doses could again reach the levels seen in the time of atmospheric testing of nuclear weapons. Restricting collective dose per unit of practice can effectively set a maximum future annual effective per caput dose from all sources stemming from that practice.

In 1977, the establishment of dose limits was of secondary concern to the establishment of cost–benefit analysis and use of collective dose. This can be seen in the wording used by ICRP in setting its dose limit for members of the public. Publication 26 states:

> "The assumption of a total risk of the order of 10^{-2} Sv^{-1} would imply restriction of the lifetime dose to the individual member of the public to 1 mSv per year. The Commission's recommended limit of 5 mSv in a year, as applied to critical groups, has been found to give this degree of safety and the Commission recommends its continued use."

In a similar manner the dose limit for workers was argued on a comparison of average doses, and therefore risk in the workforce, with average risks in industries that would be recognized as being 'safe' and not on maximum risks to be accepted.

During the 1980s there were re-evaluations of risk estimates derived from survivors of the atomic bombing at Hiroshima and Nagasaki, partly due to revisions in dosimetry. The risks from exposure were claimed to be higher than those used by ICRP and pressure began to appear for a reduction in dose limits. This represented the start, recognizable with hindsight, of rising concern for the individual. The ICRP response was initially to emphasise the principle of optimization and claim that the use of collective dose and cost–benefit analysis always ensured that individual doses were sufficiently low.

6. THE NEED FOR THE 1990 RECOMMENDATIONS

By 1989, ICRP had itself upwardly revised its estimates of risk of carcinogenesis from exposure to ionizing radiation. In 1990 it adopted new Recommendations for a 'system of radiological protection' [16,17] to replace earlier Recommendations, upon which ICRP had been building since they first appeared in Publication 26. The principles of protection recommended by the Commission were still based on the general principles given in Publication 26, but with important additions:

> "No practice involving exposures to radiation should be adopted unless it produces sufficient benefit to the exposed individuals or to society to offset the radiation detriment it causes. (The justification of a practice);
> In relation to any particular source within a practice, the magnitude of individual doses, the number of people exposed, and the likelihood of incurring exposures where these are not certain to be received should all be kept as low as reasonably achievable, economic and social factors being taken into account. This procedure should be constrained by restrictions on the doses to individuals (dose constraints), or on the risks to individuals in the case of potential exposures (risk constraints) so as to limit the inequity likely to result from the inherent economic and social judgements. (The optimization of protection);
> The exposure of individuals resulting from the combination of all the relevant practices should be subject to dose limits, or to some control of risk in the case of potential exposures. These are aimed at ensuring that no individual is exposed to radiation risks that are judged to be unacceptable from these practices in any normal circumstances. (Individual dose and risk limits.)"

The most significant change was in the principle of optimization and the introduction of the concept of a constraint. Optimization is a source related process, while limits apply to the individual to ensure protection from all controllable sources. The aim of dose limitation is to ensure that no individual is exposed to an unacceptable level of risk from all regulated sources. The constraint is an individual criterion, applied to a single source in order to ensure that the most exposed individuals are not subjected to undue risk from that source. Classical cost–benefit analysis is unable to take this into account, so the Commission established an added restriction on the optimization process; the maximum individual dose from the source, i.e., the constraint.

In the 1990 recommendations, the ALARA requirement was renamed the optimization of protection, with no intended change of meaning. In fact, however,

the shift of focus away from the word ‘reasonably’ and the emphasis of ‘optimization’ meant that in spite of increased concern for individual welfare reflected by the introduction of the concept of constraints, differential cost–benefit analysis and collective dose were still seen in many quarters as the primary means to achieve protection. Actually, it had been stressed in several earlier ICRP reports that there were many ways to achieve optimization, and in Publication 55 some alternative methods were discussed in detail. In Publication 77 [18] the Commission further weakened the link to cost–benefit analysis and collective dose. Thus concern for the protection of the individual was again being strengthened. This was a reflection of changing societal values with increasing concern about individual welfare.

7. FROM THE 1990 TO THE 2007 RECOMMENDATIONS

Since Publication 60, there has been a series of publications that have provided additional guidance for the control of exposure from radiation sources. Including the 1990 Recommendations, these reports specify some 30 different numerical values for restrictions on individual dose for differing circumstances. Furthermore, these numerical values are justified in many different ways [19]. In addition, the Commission began to develop policy guidance for protection of non-human species in Publication 91 [20]. The Commission was elaborating its policy but it was clear there were some misunderstandings of its concepts, in particular the difference between **source related** and **individual related** protection. The dose limit as defined in the 1990 Recommendations applies only in defined conditions, but many people regarded a limit as absolute. The use of higher doses for emergencies and regarding radon in homes was seriously confusing. The Commission had tried to clarify this by distinguishing between practices that added doses and interventions that subtracted doses, but the distinction was not clearly understood. Other factors concerning the Commission included excessive formality of the use of differential cost–benefit analysis and the rigid interpretation of collective dose by some practitioners. This led to initiation of a wide ranging open review of the basis for protection philosophy by the chairman at that time [21].

The ICRP Recommendations from the last 10 years emphasized controls on maximum dose or risk to the individual. There has been a corresponding reduction in emphasis on collective dose and cost–benefit analysis. Overall this reflects a shift in emphasis of the ethical position, with less attention paid to utilitarian values. Instead, the Commission has increased its emphasis on a different ethical approach, sometimes called **deontological** or **equity based** ethics, which are based on the premise that all individuals have unconditional

rights to certain levels of protection. The new 2007 Recommendations are based on this ethical policy [22].

The Commission has prepared these Recommendations after two phases of international public consultation on drafts, one in 2004 and one in 2006, as well as presentations to IRPA and other international bodies as the drafts developed. This process follows nearly a decade of a policy of transparency and involvement of those with a serious interest in protection, which the Commission expects to lead to a clear understanding and wide acceptance of its Recommendations.

There is, therefore, more continuity than change in the 2007 Recommendations; some recommendations remain because they work and are clear; others have been updated because understanding has evolved; some items have been added because there has been a void; and some concepts are better explained because more guidance is needed. The Recommendations reiterate and strengthen the importance of optimization in radiological protection and extend successful experience in implementation of this requirement for practices (now included in planned exposure situations) to other situations, i.e., emergency and existing exposure situations. They also include a commitment to environmental protection.

8. CONCLUSIONS

In this paper the development of radiological protection policy has been traced from the inception of IXRPC through its evolution to ICRP. In the 80 years of its existence, the Commission has sought to utilize the best scientific data in preparing recommendations that address practical needs. The basis of that protection policy has changed as scientific data have emerged and as the uses of radiation have broadened. In recent years the Commission has adopted a more open approach in development of its policies, publications and recommendations. This involvement of those in the affected professions has been beneficial to all parties and may be expected to continue into the future.

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SCIENTIFIC AREAS AND TOPICAL SESSIONS

II.1. DEVELOPING THE RADIATION PROTECTION FRAMEWORK

Under the motto "Towards an effective radiation safety and security regime", this scientific area covered the following topics:

- Evolving International Safety Regime, with 16 papers;
- National Infrastructures, with 44 papers;
- Education, Training and Staffing, with 50 papers;
- Safety and Security of Radiation Sources, with 32 papers.

TS II.1.1. Evolving international safety regime and TS II.1.2. Scope of radiation protection system

The Topical Sessions TS II.1.1 Evolving International Safety Regime and TS II.2.1 Scope of Radiation Protection System were merged to allow a common discussion since the issues were related to each other.

The topics on Evolving International Safety Regime included:

- International standards (harmonisation of exposure standards and codes of practice for protection);
- Legally binding undertakings and other international instruments (international conventions, regional agreements);
- Fostering information exchange (examples of dissemination information, networking, publications: outreach);
- Technical cooperation and assistance in radiation protection (strengthening national infrastructures, helping less developed countries);
- international appraisals (review and adviser missions).

The topics on Scope of Radiation Protection System included:

- General principles and criteria for protection against ionising radiation;
- Justification;
- Optimization of radiation protection;
- Types of exposure situations to be controlled (planned, existing and emergency exposures);
- Use of individual dose limit, constraints and reference levels;
- Use and misuse of collective doses;
- Exclusion and exemption.

The scientific secretary of ICRP focused in his key lecture on what the ICRP does and why, emphasizing, in particular, the recent ICRP 2007 General Recommendations, called ICRP 103, which have replaced ICRP 60.

The importance of stakeholder involvement in the development of criteria and documents was emphasised by other speakers. The process ICRP conducted with open discussions about the new Recommendations was acknowledged, particularly within workshops organized together with NEA. However, there is a need to involve all countries to move towards a global safety approach. For that, all international organizations have to be involved in discussions, including industry and professional associations. A new paradigm is taking place in which all are responsible for protection, such as legislators, regulators, managers, workers and the public. All require adequate knowledge to act appropriately. Therefore all stakeholders should be involved in the development of an International Safety Regime and associated documents. Other authors demonstrated concern about understanding the new criteria, such as the use of constraints, which may be interpreted as new, lower, de facto limits, which is not justified; others are concerned about the application of ALARA, particularly regarding legacy issues. Some examples were discussed in relation to the Russian Federation and the United States of America to illustrate this issue and draw conclusions on future application of the ALARA principles in this context.

On the development of new radiological protection and emerging scientific matters, the need to develop a shared understanding of emerging challenges of radioprotection among all relevant parties was stressed. To this aim, workshops reflecting scientific and societal issues that might challenge radiological protection in the coming years are being organized by NEA/OECD. However a process has to be established in order to involve all countries to avoid regional agreements which could impair the establishment of an International Safety Regime globally. The involvement of international organizations is fundamental to achieve a successful regime.

TS II.1.3. National infrastructures for radiation protection

The topics on National Infrastructures included:

- Legislative and statutory framework (legislation and regulations);
- Regulatory body establishment and independence (funding, staffing and training, coordination at national and international levels);
- Basic administration of radiation safety (registration, licensing, authorisation, inspections, enforcement, quality management, regulators' discretion to exempt and clear, the need for international harmonization, and the administration of intervention);

- Participation of stakeholders in the decision making process;
- Public communication and outreach.

The strengthening of national infrastructures of radiation protection requires better communication between the regulatory authority and other stakeholders in order to achieve radiation protection for patients, workers, the public and the environment. In this sense, spreading of knowledge is necessary, rather than information being viewed as the 'property' of scientists or technicians. The regulatory authority must demonstrate it is working for radiation protection of the whole population and should not assume that it has public confidence.

Risk and its perception are themes being studied, both from the point of view of a management quality system and from the point of view of communication among constituents involved in radiological safety issues. In some way, it seems that understanding the various 'sensitivities' about risk and its perception could be the key to satisfying all the actors involved in radiological safety issues and to learning how to face successful interaction with them.

At least two presentations were focused on initiatives to share the activity of updating national infrastructures. One of them proposed a model for networking, cooperation, information exchange and regulatory harmonization, with international experts providing the necessary assistance to small national organizations.

TS II.1.4. Education, training and staffing

The topics on Education, Training and Staffing included:

- Appropriate and effective education and training;
- Coordination of research and development in focus areas.

The session concluded that effective radiation protection can only be ensured by an adequate number of competent persons at appropriate levels.

In order to develop and maintain national capabilities to meet radiation protection needs, it is essential to address initial training at all levels for all personnel (this means varying educational backgrounds); and to maintain competence via appropriate specialist and refresher training. Mixing national, regional and international resources to build competence will bring greater effectiveness, accelerating implementation and providing constructive dialogue.

It was specifically concluded that education and training of regulatory body staff should be the initial focus of development for a radiation protection infrastructure. Following that, the objective must be sustainability of the expert staff and infrastructure. Finally, knowledge management must be implemented to ensure retention of expertise. It was noted that the IAEA provides a ready

resource for establishment of education and training activities, but that professional societies can play a significant role in the development of national competence. The growing international network of regional training centres was especially praised. National certification and competence recognition schemes should form part of a national strategy for building competence. They should help to build mutual recognition at regional levels and must be based on a common understanding of roles and responsibilities.

TS II.1.5. Safety and security of radiation sources

The topics on Safety and Security of Radiation Sources included:

- Prevention of unnecessary exposures, accidents or malevolent uses of radioactive sources (regulatory control, notification and inventory);
- Orphan sources (recovery, regaining control, late recognition of radiation consequences, long term management of disused sources);
- Transborder movement of radioactive sources (export–import, border monitoring and illicit traffic).

A number of common themes arose from the papers presented. There continues to be increasing recognition of the importance of, and interest in, radioactive source security. Of the papers submitted, there was almost equal representation in safety and security issues. While acknowledging this increase in priority for radioactive source security, there remains much work to do on securing sources in many countries. The international radiation protection community has a leading role to play in meeting this challenge. Accidents or potential malicious misuse of radioactive material can affect any country and all countries must work together to ensure that sources are managed safely and securely. The IAEA, through the implementation of the Code of Conduct on safety and security of radioactive sources, is doing a great job of that.

Orphan radioactive sources continue to represent a large safety and security risk due to their uncontrolled nature. It is important that efforts to detect and remediate these sources, as well as to prepare for any related emergency situations continue to be conducted. The control of radioactive sources from cradle to grave is a prerequisite to avoid orphan sources.

Conclusions — Developing the radiation protection framework

In summary, IRPA12 noted that the system of radiation protection is currently under review. The main themes discussed at the sessions dealt with ICRP and the recent review process which concluded with the ICRP 2007

Recommendations. The importance of the process of revision as well as its outcome was highlighted as an important issue for evolution of the international safety regime. Industry views on the relevance of furthering greater harmonization of the radiation protection system were presented. The application of optimization continues to be a cornerstone of radiation protection and it highlighted the importance of a transparent and traceable process to support decision makers; lessons learned from legacy sites management for future applications were also described.

The main conclusions and next steps relate to the importance of working towards ensuring harmonized, coherent and consistent implementation of the international system of radiation protection and the safety regime in the context of expanding energy needs and the expected role of nuclear energy.

An effective radiation protection infrastructure can only be ensured by maintaining an adequate number of competent persons at the appropriate levels. Therefore, education and training of competent staff is of fundamental importance to developing and maintaining national capabilities to meet radiation protection needs. For building competence, mixing national, regional and international resources will bring greater effectiveness and accelerate implementation of international standards and recommendations as well as promoting better sharing of knowledge and experience. Sustainability must be the objective and knowledge management must be addressed to ensure retention of expertise. In sum, the initial focus should be on education and training of regulatory body staff in order to develop radiation protection infrastructure. However professionals have to also be trained, since they are the main group responsible for protecting themselves, patients, the public and the environment.

A number of countries reported on the implementation of radiation protection programmes and national dose distributions and trends. There was a clear need for radiation protection support to developing countries.

There continues to be increasing recognition of the importance of, and interest in, safety and security of radioactive sources. Safety and security concerns are a global responsibility. International Safety Fundamentals SF-1[1] explicitly mentions that safety and security measures must be designed and implemented in an integrated manner. It is important that efforts to detect and remediate orphan sources be maintained, as well as to prepare for any related emergency situations. However, the avoidance of orphan sources is optimum, and for that each country needs strategies in place regarding the disposal of disused sources. Long term management of disused sources is a key challenge at the moment.

[1] Fundamental Safety Principles: Safety Fundamentals — IAEA Safety Standards Series, No. SF-1. International Atomic Energy Agency, 2006.

While acknowledging important achievements within the world community in the field of radiological safety and security, IRPA12 noted that there remains much work to do in many countries. The international radiation protection community has a leading role to play in meeting this challenge.

II.2. DEVELOPING PROTECTION POLICIES, CRITERIA, METHODS AND CULTURE

Under the motto "Providing for the Global Application of Radiation Protection", this scientific area covered the following topics:

- Scope of Radiation Protection System, with 18 papers;
- Protection of the Public and the Environment, with 111 papers;
- Occupational Radiation Protection, with 70 papers;
- Protection of Patients, with 35 papers.

TS II.2.1. Protection of the public and the environment

The area Protection of the Public and the Environment included the following topics:

- Common international issues (ICRP and IAEA approaches);
- Public radiation protection (controlling discharge of radioactive materials into the environment, safety of radioactive waste management and disposal, safe termination of activities involving radioactive substances, decommissioning, management of radioactive residues, restoration of environment);
- Protection of critical groups (the unborn child, children, the frail, the elderly, those taking certain medications etc);
- Assessing environmental exposure;
- Assessing environmental contamination (open field, urban environment, surface, commodities, foodstuffs, and environmental surveillance and sampling);
- Radiological impact on non-human species (individual vs. population and ecosystem effects, reproductive capacity, genetic effects, mortality and biological diversity);
- Framework for radiation protection of non-human species (national and international approaches, research activities, and reference organisms concept).

The keynote lecture put into perspective the long history of public protection and consideration for the evolving concept of biota protection. A relevant aspect is that both subjects have to be developed in parallel but within the same framework. Only some international organizations follow this approach.

Contributions from international organizations showed increasing developments in protection of non-human species against ionizing radiation. It is of interest to emphasize the IAEA presentation, which put international laws and developments as well as actions in some countries into perspective. The analysis of case studies supported by WNA shows that for most normal discharges into the environment no effects would be expected in biota. Presentation of the tool developed within European Project ERICA demonstrated an important development in methodologies and tools to assess the protection of animals and plants. It is clear that there is room for further development of some important aspects such as estimation of uncertainties, dosimetry, weighting factors for different types of radiation, relevant endpoints, and demonstration of suitability of the concept of reference plants and animals.

As far as environmental radioactivity monitoring, discharge and assessments are concerned, Congress recalled that the demonstration of radiation protection of the public is the main objective for worldwide monitoring activities. Some contributions are related to compliance with limits or constraints, environmental radiation quality and the long term behaviour of residual contaminations from accidents or old practices. Contributions included studies about specific types of nuclear or other industrial uses of radioisotopes, involving not only artificial but also natural radionuclides, emphasizing growing interest in this source of exposure to the population.

Other papers presented were related to effluents in routine discharges made in medical, industrial and nuclear facilities. Only one paper has addressed the use of collective doses in the population, which may reflect less interest in this metric. Finally, several papers referred to the study of parameters for the transfer of radionuclides in different ecosystems and radiological impact assessment based on measures and modelling.

It is interesting to mention that there is some evolving work in monitoring and techniques derived from improvements in instrumentation and software or requirements in decommissioning of installations including the legacy of old uranium mines.

TS II.2.2. Occupational radiation protection

Topics on Occupational Radiation Protection included:

- Obligations of employers and workers (the role of the unions);
- Risk assessment;

- Protecting the pregnant worker and the unborn;
- Dealing with occupational ‘natural’ radiation exposures (including aircrew);
- Attributability of occupational illness;
- Holistic approach to occupational radiation risks;
- Medical surveillance of radiation workers.

Due to the wide field of occupational radiation protection, it was not easy to segregate themes. Main aspects covered related to:

- Internal dosimetry, where the common theme was the necessity to improve and harmonize assessment methodologies;
- Occupational radiation protection in general;
- Methods, equipment and dosimetry;
- Examples of occupational radiation protection;
- Safety culture.

The main concerns expressed were in relation to occupational radiation protection in medical practices, where it was noted that occupational doses appear to be increasing due to the introduction of interventional radiology and new practices in nuclear medicine. Other concerns related to the necessity of training and safety culture improvements not only for big facilities but for small ones, and primarily for medical uses rather than industrial uses.

Another issue closely discussed was occupational doses in mining activities and other natural sources. UNSCEAR studies show that their importance is increasing, taking into account the decreasing importance of other activities like the nuclear fuel cycle.

Two important questions remained: Are available monitoring systems adequate for new and complex facilities, particularly in the medical arena? Is there a risk in relation to excessive use of new software for dose assessment?

TS II.2.3. Radiation protection of patients

The topics on Radiation Protection of Patients included:

- Justification of radiological medical procedures;
- Optimization of protection;
- Diagnostic reference levels (DRLs):
- Prevention of incidents and accidents in radiotherapy;
- Patient protection in diagnostic radiology (conventional, digital, CT);
- Patient protection in intervention procedures:
- Patient protection in nuclear medicine;

- Radiation protection in paediatric healthcare;
- Radiation protection of volunteers participating in biomedical research activities;
- Radiation protection of comforters and caregivers;
- Radiation protection in medico-legal exposure;
- Radiation protection in new techniques (addressing those techniques which produce real radiation protection problems e.g. particle accelerators, etc);
- Security in medical uses of radiation.

The submitted papers addressed the following subjects:

- Optimization of protection;
- Tools for implementing justification;
- Health risks resulting from medical exposures;
- Errors, incidents and accidents;
- Quality assurance;
- Internal dosimetry of radiopharmaceuticals in nuclear medicine;
- Regulatory aspects;
- Stakeholder engagement;
- Population dose estimation;
- Existing national, regional and international policies/programmes.

Contributions mainly focused on the following procedures:

- Diagnostic radiology: mammography, computerized tomography (CT) and dental radiology;
- Nuclear medicine;
- Teletherapy;
- Brachytherapy.

Medical imaging has become the largest controllable source of radiation exposure. Although it remains unregulated, the dedication to radiological protection demonstrated in the papers submitted shows a high level of awareness amongst those committed to the subject. Our aim should be to broaden knowledge of radiological protection to professionals involved in the wider practice of medicine. Training of medical staff engaged in diagnostic procedures was emphasized as an important factor to improve the protection of patients. It was particularly stressed that this training should be undertaken before the transition is made from film/screen to digital imaging. An important objective in computed tomography (CT) was reducing dose, and it was recognized that this could be achieved by tailoring protocols for the level of acceptable noise

according to the clinical indication and size of the patient (particularly in paediatric CT).

It was pointed out that the overall objective of radiological protection of patients is that benefits should outweigh risks, and no more radiation than necessary should be delivered to achieve desired image quality. Annually, 3.6 billion X ray examinations, 35 million nuclear medicine examinations and about 5 million radiotherapy treatments are performed. In terms of collective dose, radiology results in ~2 300 000 person-Sv annually, with ~800 000 person-Sv due to CT.

In the past, the main concern was focused on protecting staff, but in recent years the focus of radiation protection in medicine has shifted towards the patient. A single patient may get a higher radiation dose in 5 CTs than a staff member's lifetime exposure working in an X ray department under appropriate radiation protection conditions. However, there are some particular issues concerning occupational radiation protection, such as prevention of deterministic effects for interventional radiologists (e.g. cataracts). Key actions to implement radiation protection in diagnostic radiology, CT and intervention procedures were overviewed. The introduction of better intensifying screens as well as the use of diagnostic reference levels (DRLs) significantly improved patient protection in diagnostic radiology. Challenges related to the increasing use of digital imaging were discussed. Actions for patient dose management in CT were presented, particularly focusing on the need for dose reduction in paediatric procedures. With regard to patients undergoing intervention procedures, there is great concern over preventing deterministic effects. This is particularly critical in cardiac patients (around 6% have 3 or more interventions in their lifetime).

The IAEA established the International Action Plan for Radiological Protection of Patients in collaboration with relevant international organizations and professional bodies. The main activities developed under this action plan were summarized (diagnostic radiology, intervention radiology and radiotherapy). A web site is available at http://rpop.iaea.org with valuable information, guidance and recommendations as well as downloadable training packages.

A number of existing national, regional and international programmes related to radiation protection in medical exposures were presented (e.g. EU Dose Datamed, FORO (Ibero American Forum of Radiological and Nuclear Safety Regulatory Agencies), WHO Global Initiative).

In summary, it was concluded that:

- Referral guidelines should be encouraged as a tool for implementing justification by primary referrers, with review as necessary;
- Diagnostic reference levels (DRLs) should be used appropriately as a tool for optimization after engagement of professional bodies;

- Error reporting systems are required and should be both graded and harmonized;
- Improving the radiological protection of patients requires engagement of all involved parties to strengthen cooperation.

Conclusion — Developing protection policies, criteria, methods and culture

The basic question in this area is, "Who can take action on protection policy and criteria, what is the source of empowerment, and what knowledge is needed to act appropriately?" The answer being given in nuclear energy activities approaches seeks to build a social consensus and to gain public trust and confidence through stakeholder involvement.

Renewed interest was shown in protection of the public and the environment. It is of interest to mention that there is some evolution in work regarding environmental monitoring and techniques derived from improvements in instrumentation and software or requirements in decommissioning of installations, including the legacy of old uranium mines.

Protection of the environment from radiation (non-human species) is progressing at national and international levels. Nevertheless it was noted that this is not an urgent or important issue in developing countries, which have other priorities. Many safety criteria and guides on this topic are being developed. There have been important developments in methodologies and tools to assess the protection of animals and plants, demonstrated by the presentation of tools developed within the European Project ERICA.

Except for medical applications, occupational exposure in relation to manmade sources has decreased. In the medical field, intervention procedures were identified as a critical occupational protection issue for the practitioners. The estimated occupational collective dose due to exposure in industries involving natural radiation sources is about eight times higher than in other occupations (with high average individual effective doses and large numbers of workers, the largest component being from mining). An important issue for practical occupational radiation protection was the development and application of dose constraints; many good examples of design and operation phases were presented at IRPA12. It was also noted that a prerequisite for application of the optimization principle for occupational radiation protection is information exchange on methods for dose reduction through networking.

Based on UNSCEAR 2008 data on medical exposures, the increase in patient doses is important and requires attention. The justification of medical exposure continues to be a challenge involving quantitative assessment of detriment versus benefit. Medical imaging has become the largest controllable

source of radiation exposure. Moreover, many accidents have been reported in the medical area. How to communicate with patients and the public and a scale for rating exposure were identified as important issues. Improving the radiation protection of patients requires engagement of all involved parties to strengthen cooperation. Error reporting systems are required and should be both graded and harmonized. Reducing dose in computed tomography is important and can be achieved by tailoring protocols for the level of acceptable noise according to clinical indication and size of the patient. Diagnostic reference levels (DRLs) should be appropriately used as a tool for optimization. Additional training is important and_should be undertaken before the transition from film/screen to digital imaging. The main aim should be to broaden and share knowledge of radiation protection with involved professionals.

II.3. EMERGENCY PLANNING, PREPAREDNESS AND RESPONSE

This scientific area covered the following topics:

- Nuclear and Radiological Emergencies, with 68 papers;
- Medical Response in Emergencies, with 19 papers;
- Emergency Aftermath and Recovery, with 12 papers.

TS II.3.1. Nuclear and radiological emergencies

The topics on Nuclear and Radiological Emergencies included:

- Emergency preparedness and response (rescuers, contamination, protecting people in the aftermath of a terrorist attack);
- National capabilities for nuclear and radiological emergencies;
- Assessment of consequences (environmental impact, modelling atmospheric dispersion, radiological monitoring and data collection);
- Intervention criteria and countermeasures;
- Decision support systems;
- Dose reconstruction;
- First responders occupational protection issues;
- Public information and press communication;
- Synergism in emergency preparedness for nuclear accidents and malevolent acts;
- Criteria for dealing with different scenarios;
- Education, training, exercises and drills;

- Lessons learned in real situations;
- Regional and international assistance.

The papers in this topical session referred to most aspects of nuclear and radiological emergencies; providing significant information on risk assessments, strategies and planning; measurement capabilities; modelling capabilities; decision support; training/exercises; and actual emergencies.

There is a new focus on malicious acts. The threat of nuclear terrorism must be faced by doing everything to protect against its occurrence and through international coordination. Mass casualty events could overwhelm the national capabilities of a country with advanced resources — depending on number of casualties. The ^{210}Po incident in London was a good example; it was the most relevant radiation emergency in the past several years, leading to the need to triage thousands of people and assess levels of Po intake for hundreds.

With the re-emergence of nuclear power, nuclear countries must ensure that mistakes which lead to incidents in the past are not repeated, and that effective, harmonized and compatible emergency management capabilities exist.

If a nuclear accident or radiological emergency, or nuclear terrorist event should occur, we must be prepared to respond internationally with emergency capabilities. Thus, we need to ensure that emergency management training, response, international coordination, strategies and capabilities are shared to ensure compatible and harmonized programmes are established worldwide.

TS II.3.2. Medical response in emergencies

The topics on Medical Response in Emergencies included:

- Radiation emergency medicine systems (planning, arrangements, guidance, capabilities);
- Pre-hospital response;
- Local hospital;
- Referral hospitals;
- Multidisciplinary team approaches for medical management (ARS, local radiation injuries);
- Networks for medical response and international assistance;
- Stockpiles for radiation emergencies;
- Medical response in mass casualty events;
- Prevention and management of psychological impact;
- Public health response;
- Education and training;
- Lessons from past events.

Several WHO REMPAN[2] institutions were represented in this session. Exciting new developments in treating radiation injuries were presented, particularly from France and Japan, such as dosimetry guided surgery and cell therapy (e.g. mesenchymal stem cell injection). There are also new methods for triage using cytogenetic procedures. It was noted, however, that there is a lack of international consensus on a range of issues, such as criteria for decontamination and decorporation of radionuclides. International assistance in medical response may be needed and pre-established arrangements are essential. Not every country has developed capabilities in highly specialized treatment of radiation injuries and existing arrangements are not adequate to address the possibility of mass casualty events. Therefore arrangements for regional/international assistance should be in place. There are many legal issues related to medical response in emergencies that have to be resolved in advance in order to facilitate response, including availability of medical data in emergencies and afterwards, and transportation of patients and samples to assisting countries. The following issues were identified concerning medical assistance:

- Consensus on medical management (novel diagnostic and therapeutic strategies, new approaches for biodosimetry, prevention and management of psychological impact, protocols for decontamination/decorporation, long term follow-up);
- Legal issues, including access to medical records during and after an emergency, and informed consent of patients;
- Clarification of team roles and responsibilities;
- Transportation of patients and biological samples;
- Financial implications for existing arrangements;
- International and regional stockpile systems;
- Sustainability of expertise at the international level through professional recognition based on adequate education and training programmes;
- Research and development.

TS II.3.3. Emergency aftermath and recovery

The topics on Emergency Aftermath and Recovery included:

- Consequences and lessons of past events (e.g., Chernobyl);
- Protection of individuals living in contaminated territories after a nuclear accident or a radiological event (countermeasures and protection strategies,

[2] Radiation Emergency Medical Preparedness and Assistance Network.

criteria for the setting of reference dose levels, justification and optimisation of protection strategies, participation of stakeholders in the decision making and long term management);
- Management of contaminated foodstuffs and other commodities;
- Management of generated radioactive wastes.

A number of key issues and recommendations were presented in this session. There is a new focus on issues and approaches during later and recovery phases following an event. This requires a clear conceptual framework and reliable assessment of economic impact. Impacts and effects would be broadly distributed. This makes it essential to start planning and preparing now. Stakeholder engagement is essential in the planning process and is the key to successful decisions. It is very important that a large variety of stakeholders be involved and that scientific jargon be avoided. A multi-criteria assessment of impacts is important when dealing with the central issue of optimization.

Post-accident management and decision support systems and approaches are being actively studied. Commonalities have been identified in post-accident protection management and decision support. 'Topical tools' are being developed that provide important support for decision making in emergency situations, but they must be developed well in advance in order to be useful. Clear topical information must be provided to decision makers in advance so that it can be digested.

In the long term, populations living in contaminated territories must be individually involved in their own protection. Self-protection actions are key, but they require a framework in monitoring, health surveillance and education.

Conclusions — Emergency planning, preparedness and response

Developing, upgrading and improving nuclear or radiological emergency programmes is a challenging, but very important duty to address. It is a long term commitment that requires dedicated effort from all countries working together to develop a common strategy. The components of an effective emergency programme involve identification of threats, planning, preparedness, response and recovery. Effective emergency preparedness and response programmes are important for ensuring protection of public health and safety, workers and the environment, and mitigating the effects of any nuclear or radiological incident, whether the result of an accident, negligence or terrorist attack.

International cooperation and harmonization was recognized as necessary, but there was some frustration over how little work was presented in this area. There were also few presentations on lessons learned, except some on big exercises, such as those organized in Sweden, or the TOPOFF series in the USA.

New emergency related decision support tools were presented, like the ARGOS chemical, biological, radiological and nuclear decision support system, and the MOIRA system for assessment of alternate long term management strategies for lakes and rivers. It was recognized that tools of this type must be developed well in advance to be effective. For the period following an event there is a new focus on recovery phase. Stakeholder engagement and communication with the public are essential for success.

In the area of medical response in emergencies, new protocols in treating victims suffering from acute radiation syndrome and local injuries were presented. A multidisciplinary approach is recommended, based on careful assessment of doses to guide medical treatment, such as surgery and cell therapy. There are also new methods for triage using cytogenetic procedures. However, the need for international consensus on diagnosis, treatment and long term follow-up criteria including protocols for radionuclide decontamination/decorporation was noted. It was also clear that further research is still needed in this field. International assistance in medical response may be needed and pre-established arrangements are essential, including legal arrangements simplifying operations. It was recommended cooperation between national competent authorities and health authorities be improved in the areas of preparedness and response under emergency conventions. Effective utilization of existing regional and international capabilities, and arrangements for medical response were identified as challenges.

The enduring lesson is that consequences depend dramatically on steps taken to prepare for accident or attack. Arrangements must be in place which include clear authority and responsibility among relevant organizations. Criteria and policies for implementation of protective actions must be prepared in advance. Lack of preparation has led decision makers to make mistakes. Actions must be developed in collaboration with the public and stakeholders to ensure their support in advance. Serious efforts to accelerate international cooperation are urgently necessary. States must recognize that they may need assistance, eliminating the ‘donor/recipient’ mentality. It is now essential to elaborate and build on existing arrangements and capabilities. The importance of the IAEA Notification and Assistance Conventions was stressed in achieving this goal.

MAIN FIELD 3:
RADIATION PROTECTION AND SAFETY IN PRACTICE

BACKGROUND PLENARY III

RADIATION SAFETY IN PRACTICE: TOWARDS AN INTERNATIONAL SAFETY REGIME — THE ROLE OF THE IAEA

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Abstract

This paper presents the IAEA's activities in the area of building a harmonised global safety regime, and highlights some related challenges faced by the international nuclear community. Since 2008 marked the 50th commemorative anniversary of IAEA safety standards, the paper starts with the evolution of the process for developing safety standards and provides some examples of achieving a harmonised approach to safety. The paper also presents some near term and future challenges to be considered by the international nuclear community.

1. IAEA STATUTE AND SAFETY STANDARDS

It is a statutory function of the IAEA to develop safety standards for the protection of people and the environment, and to provide for their use. The first IAEA safety standards publication came out in 1958, and was entitled "Manual on the Safe Handling of Radioisotopes". This publication became No. 1 of the safety series. In 1961, regulations for the safe transport of radioactive material became the worldwide standard for transport safety. In 1962, the first Basic Safety Standards (BSS) was printed. These three publications formed the foundation of the future series and were followed by many other publications in the nuclear and waste safety area. Currently a new safety standards structure is being designed, with an overarching Fundamental Safety Principles document (SF-1), which can help in achieving a harmonized approach to safety worldwide.

2. CHERNOBYL — A TURNING POINT FOR THE IAEA

The 1986 Chernobyl accident was a major turning point in this process. It pushed the IAEA to reflect about its role in international cooperation to assist Member States in building and maintaining nuclear safety infrastructure to help

ensure that such a serious accident would never happen again. In 1996, the IAEA Department of Nuclear Safety was created. The new department's scope encompassed nuclear, radiation, waste and transport safety. As such, nuclear safety was now considered one of the IAEA's three pillars of nuclear cooperation. The newly established Department of Nuclear Safety helped to establish a harmonized and transparent process for development of standards involving a Commission on Safety Standards and four thematic committees. In addition, conventions and other international instruments, such as codes of conduct were agreed upon and implemented. Today, national nuclear safety infrastructure, international instruments, safety standards, and knowledge networks, combined with the various services offered by the IAEA such as peer reviews, technical cooperation missions and training activities, all comprise major elements of the global nuclear safety regime.

3. STRATEGY FOR A GLOBAL SAFETY REGIME

In all our safety activities, knowledge sharing and mutual learning are important elements. Feedback from the application of safety standards, peer reviews and from review meetings for conventions and codes of conduct are essential for continuously improving and sustaining a harmonized global safety regime. Therefore, knowledge networks at the regional and global level should be fostered and promoted. The long term strategy is to integrate various regional networks into a global nuclear safety network for sharing knowledge and experience. In doing so, safety approaches and methodologies can be considered and improved in a harmonized manner. Furthermore, knowledge and experience regarding the worldwide implementation of safety conventions and codes of conduct can be shared broadly throughout the international nuclear community.

4. THE BSS REVISION PROCESS

One of the best examples of achieving harmonization is the revision of the BSS, one of the most widely used IAEA safety standards. The revision process actively involves the broader radiation protection community, to ensure that best practices and up to date knowledge are incorporated in future regulations.

The Agency, in cooperation with cosponsoring and potential cosponsoring organizations (FAO, ILO, PAHO, NEA, WHO, UNEP, EC), initiated a revision of the BSS in 2007 with topic specific drafting meetings. The Agency has established a secretariat with the cosponsors which meets two to three times per year to coordinate the BSS revision. A technical meeting was held in July 2007

involving more than 130 participants from Member States, international organizations and international professional societies. The meeting made recommendations on BSS revisions, stating in particular that the revised edition should follow the 2007 ICRP Recommendations to the extent possible. The Agency consults with Member States during the development and approval processes. All IAEA Safety Standards Committees are involved in the process, with standing bodies of technical experts nominated by Member States, mainly regulators representatives. The leading committee is the Radiation Safety Standards Committee (RASSC), which reviewed a draft of the revised BSS at its meetings in November 2008. Approval of the committees is required before the revised BSS draft will be sent to all Member States of the IAEA, and other cosponsoring UN organizations, for a 120 day comment period. A draft of the revised BSS is expected to be sent to Member States for comment in 2010. Each Member State should assure all stakeholders will be involved in the consultation process. The final stage will be endorsement by the IAEA Commission on Safety Standards and approval by the Board of Governors. It is expected that IAEA Member States will use the revised BSS as the basis for regulation of radiation protection for all types of exposures and facilities. It is also expected that all cosponsors and potential cosponsors will support the final document as an International Safety Standard.

The structure of the revised BSS follows the ICRP 103 approach on three exposure situations — planned, emergency, and existing exposure situations. Within each exposure situation, there are three exposure categories: occupational, public and medical exposure. The new format of the IAEA Safety Standards with overarching requirements will also be considered in the BSS revision.

It was agreed not to provide dose constraint values for use in the optimization process for planned exposure situations, but requirements allow the operator or regulator to select values based on available good practice for the type of facility. The revised BSS follows the ICRP approach in replacing ‘action levels’ with ‘reference levels’ in the optimization process for emergency and existing exposure situations. Regarding exemption and clearance, the revised BSS now includes activity concentration levels for bulk quantities published in the IAEA Safety Guide RS-G-1.7. Additionally, the revised BSS now includes the categorization scheme for radioactive sources, which was published in RS-G-1.10.

An important outstanding issue which needs further discussion are requirements for radon in workplaces as well as in personal dwellings.

5. CLASSIFICATION OF WASTE

One of the main areas for a safety network to share knowledge and experience is radioactive waste management. Nowadays, the global safety regime in this area has different layers at national and international levels. The first international legally binding agreement in this field is the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste management. The IAEA provides the Secretariat of this convention to the international community.

Another option for knowledge sharing takes place through international conferences, symposia, projects and review services for the development of RWM strategies, and for the demonstration of safety regarding radioactive waste management activities and facilities.

At the national level, regulatory bodies for the safety of the radioactive waste management and implementing organizations are key contributors to the success of the safety network.

An example of the harmonization process for developing safety standards is the recently (September 2008) approved Safety Guide for the Classification of Radioactive Waste. For the recent revision of the safety guide — which is a widely used document intended to create better worldwide communication and development of harmonized waste strategies — it was necessary to open a broad discussion on the content of the revised version. Through several international conferences and workshops, including a national gathering of radioactive waste operators, international consensus was achieved that international standards on radioactive waste classification should encompass all waste types, including those containing naturally occurring radioactive materials (NORM) and disused sealed sources. Also, it was agreed that international standards in this area should be centred on long term management of waste.

As an example, the global phosphate industry is one of the largest producers of residues containing naturally occurring radioactive materials, specifically phosphogypsum. A variety of national regulatory approaches have been adopted across the globe with regard to acceptability of the use of commercial products derived from phosphogypsum residues. A clear need has been identified by the IAEA for a coherent, consistent and sustainable global regulatory approach to NORM industries such as the phosphate industry, in order to recycle NORM residues where possible and reuse them for economic development while complying with international standards for the radiation protection of the public and the environment. In order to encourage and promote a global solution to these issues, a coordinated effort is required for harmonization through the use of realistic, evidenced based, radiological assessment models. A collaborative approach — coordinated by the IAEA — has been adopted on this project, which

involves a global, multi-disciplinary team comprised of regulators, research institutes and operators from around the world. The ongoing process of consultation and analysis is expected to continue until 2011.

Now I would like to share with you the outcomes of three round table discussions organized by the IAEA during the 52nd General Conference. The conclusions pointed out the need for integrated efforts at the national and international level. If the international nuclear community wants to meet current challenges and improve safety, it must work towards a harmonised nuclear safety regime.

6. PROTECTION OF PATIENTS

The first round table was on protection of patients. The main outcome of the discussion was recognition that medical exposure continues to be overwhelmingly the most significant manmade source of exposure to the population of ionizing irradiation. It is imperative for all stakeholders involved in the radiation protection of patients to remain vigilant as new technologies, such as multi-detector CT and PET/CT, and complex medical exposure procedures, such as intensity modulated radiation therapy, are introduced into practice at a rapid pace. Within Member States, it is essential that there are close interactions between the national nuclear/radiation regulatory body, national health authority and national labour authority in relation to radiation protection and safety in this crosscutting activity. Furthermore, the IAEA should ensure that its interactions with Member States involve all relevant authorities. The IAEA should make efforts to ensure that all health professionals are given the opportunity to learn from accidental, unintended and unnecessary medical exposures and to share information in expert networks and educational reporting systems. Information and guidance needs to reach all facilities where medical exposure is undertaken. Special consideration needs to be given to issues in connection with second hand equipment delivery and the delivery of very advanced technology to end users with less advanced training. The global impact of IAEA initiatives with respect to radiation protection of patients will be enhanced through continued collaboration with other international organizations such as the World Health Organization (WHO) and the International Labour Organization (ILO).

Training in radiation protection across a wide spectrum of health professionals continues to underpin radiation protection of the patient, and collaboration with professional bodies will enhance efforts in this respect. Consideration needs to be given to tailoring training to regional needs. The issue of principles of justification and optimization not being well understood by health professionals outside of radiology, nuclear medicine and radiotherapy was also discussed at the

round table. While the increased spread of medical technologies utilizing ionizing radiation brings significant benefit to the global population, there are studies indicating that several tens of percent of radiological examinations might be unnecessary. Tools to improve this situation should be explored.

Ensuring worldwide radiation protection of patients is a complex task. The IAEA, in responding to the importance of this issue, prepared the International Action Plan (IAP) for the Radiological Protection of Patients in consultation with the following organizations of the United Nations System: the World Health Organization (WHO), the Pan American Health Organization (PAHO), the United Nations Scientific Committee on the Effect of Atomic Radiation (UNSCEAR) and the following other organizations and professional bodies: the European Commission (EC), the International Commission on Radiation Units and Measurements (ICRU), the International Commission on Radiological Protection (ICRP), the International Electrotechnical Commission (IEC), the International Organization for Medical Physics (IOMP), the International Organization for Standardization (ISO), the International Radiation Protection Association (IRPA), the International Society of Radiation Oncology (ISRO), the International Society of Radiographers and Radiological Technologists (ISRRT), the International Society of Radiology (ISR), and the World Federation of Nuclear Medicine and Biology (WFNMB). After approval in 2002, a steering panel was established in 2003 based on representatives of the above organizations (and the European Society for Therapeutic Radiology and Oncology – ESTRO) and external experts, to keep the implementation of IAP activities under review, provide continuing guidance on the overall approach to implementation of the IAP and propose adjustments. This steering panel has reviewed progress in 2004, 2006 and 2008, and made additional prioritized concrete recommendations for action. Issues considered under the IAP include, for example: (i) education and training, especially addressing lack of qualified personnel and lack of awareness and education in patient protection issues; (ii) guidance, to address variations in dose used for given medical examinations and issues around justification of medical exposure; and (iii) information exchange, based on a lack of learning from the occurrence of global safety related events. The IAEA has seen several major developments in all these issues under implementation of the IAP, including the development of a dedicated website for the radiation protection of patients, with a hit rate of 500 000 per month; the development of several training packages on these topics which have been made freely available along with guidance publications; and ongoing developments regarding safety related information systems for interventional radiology and radiotherapy.

7. DELAYS AND DENIALS OF SHIPMENTS

Delays and denials of shipments of radioactive material are a developing problem and were the subject of another round table discussion. A powerful argument was made by a national regulator that the correct response of a regulator is to ensure a safe and sustainable transport infrastructure that services the beneficial use of radioactive material in society. It became clear during discussions that the ability of people to interface with the International Steering Committee on Denial of Shipment and the IAEA Secretariat during instances of denial could be improved through better communication channels. There was a clear need for political action to ensure national focal points are identified and that they are providing an effective bridge between the IAEA Secretariat and their national constituents. A key factor was interdependency between Member States. Unless national focal points are established, a state cannot respond to denial reports, and its industry will face problems in lodging denial reports because there is no communication channel in their country. Governments need to be sensitive to this problem and support solutions to empower those seeking to solve the problem.

8. UPSURGE OF THE URANIUM MINING AND PRODUCTION INDUSTRY

In recognition of increasing uranium demand due to a nuclear power 'renaissance' and the resulting surge in nuclear fuel prices, countries investing more in uranium exploration. The IAEA is facilitating the transfer of information and knowledge from states with extensive experience in uranium mining and production to 'newcomers' to the sector, as well as providing its own expertise.

The final round table discussion was thus on the upsurge of the uranium mining and the production industry as well as identification and discussion of key safety and environmental issues. These key issues included legacy sites left behind by poor past practices and the lack of an adequate regulatory structure in many developing countries which are involved in the exploitation of uranium for the first time. A number of programmes have been initiated by the IAEA to assist Member States involved in uranium exploration and production. In addition to Agency initiatives, the uranium production industry — in conjunction with the IAEA — has developed its own initiatives to assist in moving towards the goal of implementing consistent global 'best practices' and social responsibility in the industry. The Agency is actively pursuing cooperative approaches with other organizations such as the World Bank, the Organization for Security and Co-operation in Europe (OSCE), and the United Nations Development Programme

(UNDP), and has adopted regional approaches to assist Member States in addressing common problems in Africa, Asia and South America. Another important Agency initiative is resurrection of the IAEA Uranium Production Site Assessment Team peer review programme (UPSAT). The UPSAT programme provides an effective mechanism for the transfer of 'best practice' principles from experienced operators to smaller, less experienced operators.

9. CONCLUSIONS

In conclusion, the international nuclear community must work towards harmonizing implementation of radiation, waste, nuclear and transport safety and security. This can be achieved, in part, through the application of the overarching IAEA Safety Fundamentals document and the promotion of networks and communities of regulators, industry and users.

At the international level, the Agency has started to integrate the views of regulators and users throughout the world. However, at the national level you are the ones who can ensure that radiation protection standards are met. This is particularly important due to the revival of nuclear energy, uranium mining and development of new technologies in the medical area.

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REGIONAL APPROACH TO REACH HARMONIZATION IN RADIATION PROTECTION: EXAMPLE EURATOM DIRECTIVES. THE REVISION OF THE EURATOM BASIC SAFETY STANDARDS

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Abstract

The European Union currently comprises 27 Member States. Ever since the signature of the treaty establishing the European Atomic Energy Community (EURATOM) in 1957, the Community has played a leading role in setting radiation protection standards. These standards are of a binding nature and the European Commission has important powers of enforcement. This paper briefly explains the role of different EU institutions, the specific provisions under Chapter 3 "Health and Safety" of the EURATOM Treaty for the establishment of the Euratom Basic Safety Standards and the current legal 'acquis'. The European Commission has undertaken a fundamental revision of the Basic Safety Standards as well as a consolidation of the acquis. Progress with this revision, its relationship to the new ICRP recommendations and with the ongoing revision of international standards (IAEA) as well as a few important topical issues are discussed.

1. RADIOLOGICAL PROTECTION UNDER THE EURATOM TREATY

Further to the now obsolete treaty establishing the European Community for Coal and Steel (1955), two treaties were signed in 1957, one establishing the European Atomic Energy Community (Euratom), the other the European Economic Community (EEC, now referred to as EC). The Euratom Treaty aimed to create the conditions for access of all Member States (only six at that time) to promising developments in nuclear power.

While the EC treaty has gone through several revisions relating to its scope and decision making procedures, pending the adoption of the Treaty of Lisbon, the Euratom Treaty has remained unchanged. The two treaties are managed through the same three major institutions: the European Commission (EC), the European Parliament (EP) and the European Council. While under the EC Treaty the European Parliament evolved to take an important part in the decision making process (with full codecision powers in certain areas, such as environmental policy), it can only make recommendations under Euratom Treaty provisions.

The Council of Ministers eventually decides on new legal acts, by unanimity in certain areas under the EC Treaty, by qualified majority for other areas, as well as under Euratom Treaty provisions. The European Commission has the essential right of initiative; it is for the commission to undertake new legislation and to make a proposal to the council and to the parliament, as appropriate.

The Euratom Treaty also provides the basis for radiological protection in the European Union. The obligation to establish uniform safety standards is laid down in Article 2.b of the Euratom Treaty and further specified in Title II, Chapter 3, on "Health and Safety". Article 2.b of the Treaty stipulates that "in order to perform its task, the Community shall, as provided for in this Treaty…. establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied". Article 218 of the Treaty underlines the importance for Euratom of the basic standards, as these had to be determined within one year of the Treaty's entry into force.

Article 2.b is developed in Title II, Chapter 3 of the Treaty ("Health and Safety"), which defines, among other provisions, the concept of "basic safety standards" (Article 30), the procedure to be followed for their adoption (Article 31), and the possibility of revising or supplementing them (Article 32).

The founding fathers of the Treaty were well aware of the health risks resulting from ionising radiation. The subjacent idea was to provide the same level of protection to all the workers and citizens of the Community, which implied that the Community needed to be vested with the necessary powers: the capacity to lay down uniform basic safety standards (Articles 31 and 32), the power to verify facilities for monitoring environmental radioactivity (Article 35), the obligation for Member States to obtain the Commission's opinion before authorising releases of radioactive substances into the environment (Article 37) or before carrying out "dangerous experiments" (Article 34).

Article 30 of the Treaty defines the basic safety standards as follows: "Basic standards shall be laid down within the Community for the protection of the health of workers and the general public against the dangers arising from ionizing radiations. The expression 'basic standards' means:

(a) maximum permissible doses compatible with adequate safety;
(b) maximum permissible levels of exposure and contamination;
(c) the fundamental principles governing the health surveillance of workers."

The first standards were already adopted in 1959: "Directives laying down the basic standards for the protection of the health of workers and the general public against the dangers arising from ionising radiations". The provisions of this first piece of legislation already reflected an interpretation of the definition given in Article 30 that took into account what was really needed for achieving

the best possible health protection of workers and the population, an interpretation that went well beyond the strict wording of Article 30.

The BSS have evolved since then as scientific knowledge on the effects of ionizing radiation has improved, duly taking into account recommendations from the International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU); both organisations are internationally recognised for their assessments of the state of the art in their respective fields. The BSS have also been revised to take into account practical experience with operational radiation protection. Throughout these 49 years there has been a continued trend to strengthen regulatory control of radiation exposure while pursuing a uniform implementation of requirements in national legislation. The most recent version of the BSS is contained in Council Directive 96/29/EURATOM, of 13 May 1996, laying down basic safety standards for the health protection of the general public and workers against the dangers of ionizing radiation ("BSS Directive").

From 1957 to 1986, only directives dealing with the BSS (as consequently modified or replaced) were adopted, supplemented by one directive dealing with the radiation protection of patients. The Chernobyl accident then highlighted the need for additional measures in order to reinforce the system of health protection by covering all different fields where a regulatory and coordinated action at the Community level could contribute to reduce radiation risks.

Today the Community acquis, derived from Title II, Chapter 3, constitutes a consistent and evolutionary legislative framework, with the BSS Directive as a principal piece of legislation, supplemented by more than 25 instruments of both binding and non-binding nature, covering the following fields:

- Medical applications of ionising radiation: Directive 97/43/EURATOM;
- Information in case of radiological emergency: Decision 87/600/EURATOM and Directive 89/618;
- Protection of 'outside workers': Directive 90/641/EURATOM;
- Shipments of radioactive waste and substances: Directives 92/3/EURATOM and 2006/117, and Regulation (EURATOM) No 1493/93;
- Foodstuffs and feeding stuffs regulations following the Chernobyl accident: Regulation (EURATOM) No 737/90 and special provisions in case of a future accident, Regulation (EURATOM) No 3954/87, as completed;
- Control of high activity sealed radioactive sources and orphan sources: Directive 2003/122/EURATOM ("HASS Directive").

It is worth recalling that, while European legislation provides for a binding framework, the responsibility for implementing and enforcing the European legislation at national level rests with the Member States.

In order to assist Member States in implementing these Euratom provisions, the Commission has issued communications with information relevant for Member States and stakeholders (communications concerning the implementation of Directive 96/29/EURATOM and Directive 89/618/EURATOM), as well as a number of publications (the "Radiation Protection Series"), some of them resulting from specific contract studies or from activities of the Group of Experts provided for in Article 31 EURATOM
(see http://ec.europa.eu/energy/nuclear/radioprotection/publication_en.htm).

1.1. Article 31 of the Euratom Treaty

1.1.1. The procedure

The procedure by which the Basic Safety Standards are established is laid down in Article 31. The Commission needs to consult a group of scientific experts established under Article 31 of the treaty on all legislative proposals based on this article. The Commission Proposal is first submitted to the European Economic and Social Committee (EESC) for its opinion. Upon incorporation of all or part of the observations of the EESC, the Commission adopts the final proposal to be formally submitted to the Council, which then has to obtain the opinion of the European Parliament on it ("consultation procedure"). The Council decides by qualified majority.

Subsequently, directives need to be transposed in national legislation, for which a deadline (usually two years) is given to Member States. Draft legislation is submitted to the Commission under Article 33, so as to give the Commission the opportunity to make recommendations on the national legislation before this is adopted and published.

Unlike directives, regulations are binding in their entirety and directly applicable in all Member States.

1.1.2. The Article 31 Group of Scientific Experts

Under Article 31, a standing group of scientific experts has been established, which is attached to the Commission and has advisory status.

By virtue of the very high standing of its members, and their qualification in the fields of radiation protection and public health, the group of scientific experts referred to in Article 31 of the EURATOM Treaty (the "Article 31 GoE") is called upon to assume the all important function of adviser to the Commission on preparing the basic standards to be proposed by the latter. According to the requirements of Article 31, when putting forward proposals concerning the basic standards, the Commission convenes the group so that it may formally obtain an

expert opinion to enable it to guide its decisions and make the requisite choices. Such decisions are collectively given by the group whose members, each being appointed on a personal basis, speak on their own behalf and act independently of all external influence. They do not represent Member States or other bodies.

The Commission may convene the group not only on the occasions specifically laid down in the treaty, but also whenever it considers such action to be necessary. A schedule of at least two meetings a year permits the Commission to keep up a fruitful dialogue with the Group, whilst periodically requesting exchanges of view and guidance on any major problem affecting radiation protection. If necessary, additional meetings can be held or matters can be dealt with in written procedure.

The members of the group are appointed for a term of five years, renewable by the Scientific and Technical Committee set up in compliance with Article 134 of the treaty.

1.2. Basic safety standards

1.2.1. Current legislation

The current Basic Safety Standards Directive (96/29/EURATOM) introduced some new features in 1996 in order to meet the prevailing needs at that time. Title VII was introduced for the regulatory control of work activities involving natural radiation sources. With the exception of aircrew exposure, the directive left responsibility for the identification of industries processing naturally occurring radioactive materials (NORM) and of workplaces with high radon concentrations with national authorities. The concepts of exemption and clearance were introduced, but it was up to Member States to establish clearance levels, allowing for general criteria (e.g., individual doses of less than about 10 μSv) and community guidance. In Title IX on intervention situations, Member States were required to seek cooperation in order to cope with transboundary nuclear accidents or radiological emergencies, but there was no translation of this requirement into legal or operational terms.

This flexibility was needed in order to achieve consensus on the inclusion of these new features at a time when there was little experience with such matters, which made it difficult to judge their impact and regulatory burden. The experience gathered since 1996 with transposition in national legislation (due by May 2000) and operational implementation demonstrated a need for enhanced harmonization. The identification of NORM industries by Member States was not fully coherent, different clearance levels were introduced for the dismantling of nuclear installations, and national intervention plans, e.g., with regard to the distribution of stable iodine, proved to differ considerably between some neighbouring countries.

To some degree, harmonization was achieved through guidance documents adopted by the Group of Experts established under Article 31 of the Euratom Treaty. For instance, the publication Radiation Protection 122, Part I, introducing default values for clearance of any type of material, contributed very much to the harmonization of levels laid down in national legislation [1]. It is now time, however, to make such guidance legally binding so that further harmonization is achieved.

The Commission also undertakes the simplification of its acquis of Community legislation by the codification of related acts (without modification, e.g., amendments or complementary legislation) or recasting these if necessary (e.g., allowing for different definitions). In the radiation protection area, Chapter 3, "Health and Safety", of the Euratom Treaty has been implemented for 50 years. An important step towards simplification of this acquis would be the consolidation of all directives in the Basic Safety Standards (Medical Directive 99/43/EURATOM), the directives on outside workers and on informing the public with regard to radiological emergencies, and the directive on high activity sealed sources and orphan sources (Council Directives 90/641, 89/618, and 2003/122 respectively).

This consolidation would promote the coherence of definitions and requirements in all directives and the association of specific and general requirements. For instance, incorporation of a Medical Directive would avoid protection dissociation regarding patients and medical staff, e.g., in interventional radiology. It also permits a better perspective of the so-called "medicolegal exposures".

1.2.2. Revision of the Basic Safety Standards

International context

Revision of the Euratom Basic Safety Standards will take into account the new ICRP Recommendations [2]. While these do not necessarily require major changes in regulatory requirements, we believe they offer a much more coherent and understandable framework. Hence the Commission will undertake to structure requirements along the concepts of planned, existing and emergency situations, and highlight the role of optimisation below suitable constraints and reference levels. The societal criteria determining the acceptability of levels of constraints and reference levels will need to be carefully translated in regulatory terms, with due allowance for subsidiarity Community and national requirements.

The European Commission is committed to joining cosponsors of the international Basic Safety Standards (IAEA, NEA, ILO, WHO, PAHO). The Commission is active in the Secretariat with revision of the BSS, and contributes to the drafting of different chapters. The IAEA has participated in all Working

Party meetings of the Article 31 Group of Experts dedicated to revision of the Euratom Basic Safety Standards. Indeed, we believe that harmonization at the international level will strengthen radiation protection throughout the world.

The Community's Group of Experts has established a work programme for revision of the Basic Safety Standards. It followed a topical approach, leaving actual drafting of the Basic Safety Standards to the end. Working parties have been established to take on board the redrafting of requirements on exemption and clearance, on natural radiation sources, and on a graded approach to regulatory control. Further work needs to be undertaken on occupational exposure (including outside workers) and emergency preparedness. In November, a complete outline of the structure of the new BSS and of prospects for consolidation with other directives was approved. It was decided to entrust the actual drafting of the full directive, including further topical issues as well as the recast of the other directives, to a working party "recast". The progress which has been achieved so far, pending final endorsement by the Group of Experts, is summarised below.

Structure

The structure of the new Basic Safety Standards Directive had to be revised thoroughly, first to accommodate incorporation of the other directives as part of the recast process and second, to allow for the distinction introduced by ICRP between planned, emergency and existing exposure situations. The EC has endorsed this distinction and provisions for emergency and existing exposure situations have been laid down in specific titles (Title XI and XII respectively) but it is not always straightforward; for instance, would activities involving natural radiation sources fit into planned or existing situations? In the proposed structure it is also thought preferable to have, for example, a title on "the protection of workers" (Title VII), which deals with all aspects of occupational exposure, including emergency workers and the follow-up to accidental exposure of workers. Hence in the EC structure there is a Title VI on "justification and regulatory control of planned exposure situations", but the chapters on the protection of workers, patients and members of the public (VII, VIII, IX respectively) are not part of an overall title on "planned exposure situations".

In the new structure, the overall "system of protection" has been taken up in Title III. It mirrors exactly the wording used in ICRP Publication 103 and gives the most weight to the principle of optimisation subject to constraints and reference levels. The bands of constraints/reference levels proposed by ICRP (0–1 mSv, 1–20 mSv, 100–200 mSv) will be introduced explicitly, including the societal criteria that ICRP listed for each band (Table 5 of Publication 103). Title IV lays down requirements for regulatory control and puts requirements on

Member States' regulatory authorities for the management of all three exposure situations. This title also incorporates requirements relating to the control of high activity sealed sources (HASS). Directive 2003/122 on HASS and orphan sources has very specific features which are not easily incorporated elsewhere in the new directive.

The overall schedule of the new recast directive is given in Table 1. Incorporation of the requirements of the five directives in each heading is not straightforward: no changes are allowed to the content of the requirements, unless really necessary and duly justified. It is essential to keep track of the changes in order to facilitate the later adoption process.

Exemption and clearance

Directive 96/29 introduced exemption values in terms of activity (Bq) and activity concentration (Bq/g). In addition, the reuse or recycling of materials with negligible levels of contamination, especially arising from dismantling, can be authorised so the materials are released from regulatory requirements, subject to complying with clearance levels. The clearance levels should be established in such a way that individual doses would be below about 10 μSv (and collective doses below 1 man Sv), taking European Community guidance into account. Such guidance has been adopted by the Group of Experts for specific materials

TABLE 1. OUTLINE OF NEW EURATOM BSS

Preamble	
Title I	Subject Matter and Scope
Title II	Definitions
Title III	System of Protection
Title IV	Responsibilities for Regulatory Control
Title V	Requirements for Education and Training
Title VI	Justification and Regulatory Control of Planned Exposure Situations
Title VII	Protection of Workers, Apprentices and Students
Title VIII	Protection of Patients and Other Individuals Submitted to Medical Exposure
Title IX	Protection of Members of the Public
Title X	Protection of the Environment
Title XI	Emergency Exposure Situations
Title XII	Existing Exposure Situations
Title XIII	Final Provisions

such as metals (scenarios for steel, copper and aluminium), buildings and building rubble, and default values for any type of material (Radiation Protection 122 Part I).

Meanwhile the IAEA adopted similar guidance in RS-G-1.7 [3], on the basis of scenarios to a large extent inspired by those underlying RP 122. The IAEA levels were not specifically developed for the purpose of clearance, but it was suggested that they be used for this purpose. The Group of Experts came to the conclusion that for the sake of international harmonization RS-G-1.7 values should be considered rather than those in RP-122. A study will investigate whether differences between the two approaches and series of values has any significance in practical terms.

The experts also introduced the same concentration values for applying concepts of exemption and clearance. While the activity values for exemption will be kept, the concentration values will be those for clearance. Investigation will be undertaken to determine whether lowering exemption values will affect any consumer goods placed on the market. A single set of numbers would be of great benefit to the simplification and understanding of the Basic Safety Standards.

Natural radiation sources

The working party on natural radiation sources undertook the harmonization of identification and regulatory control of NORM industries. The working party agreed on a "positive list" of industry types that will be subject to controls in all Member States. It will be the task of national authorities to inform concerned industries and make sure that they understand the radiation protection issue and take, if necessary, appropriate measures to reduce exposures within the overall health and safety policy of the undertaking.

The industries (those listed and such other industries as identified at the national level) will also be requested to investigate activity concentration levels at all points of their process. Where such levels exceed 1 Bq/g for the U-238 or the Th-232 series, or 10 Bq/g for K-40, the industries will need to assess the resulting exposure to workers. On the basis of this assessment, a graded approach to regulatory control will be applied. Where doses are all below 1 mSv, the practice is exempted. Where doses are in the range of 1 to 6 mSv per year the only requirement is to review whether optimisation calls for a further reduction in exposures, and whether exposures remain broadly the same over many years. In view of the fact that there is in general no risk of accidental exposure, there is no need for individual dosimetry or medical surveillance. In the exceptional case that doses exceed 6 mSv per year, the full set of requirements for classified workers will apply.

With regard to the management of effluents and residues, these should comply with similar constraints as other practices (e.g., in the range 0.3–1 mSv per year) and probably lead to a limitation of total annual activities discharged. There is a need for caution with regard to recycling of NORM residues in building materials. The exemption level of 1 Bq/g is too high for this purpose, hence any recycling in building materials and any mixing of residues with other materials in view of such recycling must be authorised.

The working party also looked into requirements for building materials in general. On the basis of earlier guidance (in Radiation Protection 112), requirements for the use and marketing of building materials will be incorporated in the Basic Safety Standards. The activity concentration index I (weighted sum of Ra-226, Th-232 and K-40 activities) may lead to a classification for exemption or some form of regulatory control. Radon in workplaces will be subject to a reference level of 500 Bq m^{-3}.

The identification of workplaces where radon might be a problem will be part of a national action plan which will also cover radon in dwellings. The action plan will offer transparent information on the scope and objectives pursued at national or regional levels, define the rationale for the conduct of surveys and for delineation of radon prone areas, and establish reference levels (a maximum of 400 Bq m^{-3} for existing dwellings and 200 Bq m^{-3} for new dwellings) and building codes.

Currently, radon in dwellings is excluded from the scope of Directive 96/29/EURATOM and covered by a European Commission Recommendation (90/143/EURATOM). Raising recommendations to the level of binding requirements was prompted by recent findings of epidemiological surveys, confirming expected lung cancer risk at levels in the order of 100 Bq m^{-3}.

2. GRADED APPROACH TO REGULATORY CONTROL

Current requirements are part of a two tier system: reporting of practices above exemption levels or other criteria, and prior authorisation for broad categories of practices. The IAEA had introduced a three tier system: notification, registration and licensing. The working party identified which types of practices will be subject to each pillar, which general conditions need to be fulfilled and what the content is of requirements laid down upon registration or as part of a specific operating licence.

The current system for exemption of apparatus and consumer goods relies very much on the concept of ‘type approval’. This concept was not worked out further, and there is a lack of harmonization of conditions for type approval and corresponding decisions in the EU. This will need to be worked out in more detail

and a system of mutual recognition (or at least allowance for) type approvals granted in other Member States will be introduced.

2.1. Prospects

The Group of Experts under Article 31 of the Euratom Treaty had planned to finalise the text for the new directive by November 2009 under the mandate of the current group. The experts' text and their opinion will be the basis of a European Commission proposal scheduled for 2010 (including preparation of the interinstitutional recast procedure). Adoption of the European Commission's proposal by the European Council may take another few years and, taking into account time granted for transposition into national legislation, requirements may not become truly effective before 2014.

Meanwhile the European Commission is closely following revision of the international Basic Safety Standards. As a result of European Union decision making rules, the EC has so far never formally cosponsored the international standards. It is now envisaged to do so, in the same way as for the document laying down safety fundamentals.

A European Commission decision confirming co-sponsorship of the international Basic Safety Standards, upon consensus of the European Council, will need to allow for possible differences in requirements under Euratom standards. The aim, however, is to harmonise the definitions and requirements much as possible, basing them both on ICRP recommendations.

It should be emphasised, however, that Euratom standards will still look very different compared to international standards, because the structures are not the same and neither is the amount of detail in existing legislation or requirements needing to be incorporated, as well as because of the legally binding nature of the Euratom standards, applicable to the 27 Member States of the European Union.

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INTER-AGENCY COMMITTEE ON RADIATION SAFETY: AN EFFECTIVE TOOL FOR HARMONIZATION

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Abstract

In 1990, an important step towards international harmonization of radiation protection and safety took place. At the initiative of the IAEA, representatives of seven intergovernmental and three non-governmental professional organizations formed the Interagency Committee on Radiation Safety (IACRS). The IACRS serves as a forum for consultation on and collaboration in radiation safety matters between international organizations. Topics include, for instance, ICRP recommendations and Basic Safety Standards as well as ad hoc issues such as radiation protection at security screening. This paper presents the different mandates/scopes of the participating organizations, highlights the importance of co-sponsorships and provides an outlook on the key challenges of further IACRS activities.

1. INTRODUCTION

IACRS — the Inter-Agency Committee on Radiation Safety — was constituted as a forum for consultation on and collaboration in radiation safety matters between the secretariats of international organizations on the initiative of the IAEA in March 1990. It was an important step towards international harmonization of radiation protection and safety.

Already at that time one of the main issues to be addressed was ICRP general recommendations (at that time ICRP60), their implementation and the revision of international safety requirements.

Through IACRS, international organizations contributed significantly to evolution of the scientific and legal framework in the field of radiation protection. The committee operates based on agreed terms of reference which are reviewed as needed approximately every four years; the latest update was made in August 2001.

Regular meetings (rotating the chair among member organizations) and electronic communication are the basis for successful information exchange between the organizations (see Table 1).

2. OBJECTIVE

The objective of IACRS is to promote consistency and coordination of policies with respect to areas of common interest in radiation protection and safety, such as:

- Applying principles, criteria and standards and transferring them into regulatory terms;
- Coordinating research and development;

TABLE 1. PAST IACRS MEETINGS

IACRS meeting no.	Year	City	Host Organization
IACRS 1	1990	Vienna	IAEA
IACRS 2	1991	Geneva	WHO
IACRS 3	1992	Brussels	EC
IACRS 4	1993	Washington	PAHO
IACRS 5	1995	Rome	FAO
IACRS 6	1996	Vienna	IAEA
IACRS 7	1998	Vienna	IAEA
IACRS 8	1999	Geneva	ILO
IACRS 9	2001	Paris	OECD/NEA
IACRS 10	2003	Luxemburg	EC
IACRS 11	2005	Washington	PAHO
IACRS 12	2006	Geneva	WHO
IACRS 13	2008	Vienna	IAEA

- Advancing capacity building, including education and training;
- Promoting widespread information and sharing of knowledge;
- Facilitating the transfer of new technology (in consideration of radiation safety aspects);
- Providing services in radiation safety.

3. MANDATE / ROLE

The mandate of IACRS is to provide a forum for the exchange of information between secretariats of agencies/organizations on their respective activities. The purpose is to ensure as far as possible the harmonization of respective plans and activities relating to radiation safety in order to avoid unnecessary duplication of radiation safety standards and recommendations. An important obligation of IACRS members is to report back to their respective agencies/organizations on international activities.

4. MEMBERS AND OBSERVERS

Table 2 shows the current composition of IACRS. Six organizations of the UN system, two other member organizations and five observer organizations are involved via IACRS in the discussion on the scientific and legal framework in the field of radiation safety. The responsibilities and tasks of respective member organizations are briefly described below. More details on the structure and function of these organizations as well as on the observer organizations can be found on their websites (see Table 2).

4.1. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR)

UNSCEAR is the official international authority on levels and effects of ionizing radiation, used for peaceful as well as military purposes and derived from natural as well as man-made sources. This committee systematically reviews levels, effects and risks of exposure to ionizing radiation. It has identified emerging issues (such as the importance of exposures to natural sources of radiation and to radiation in medicine) and enhanced knowledge for the UN General Assembly and the scientific community, as well as the public.

TABLE 2. COMPOSITION OF IACRS IN OVERVIEW

Members of IACRS		Observers to IACRS
Organizations of the UN system	Other entities	
UNSCEAR http://www.unscear.org	OECD/NEA http://www.nea.org	ICRP http://www.icrp.org
IAEA http://www.iaea.org	European Commission http://www.ec.europa.eu	ICRU http://www.icru.org
ILO http://www.ilo.org		IEC http://www.iec.ch
WHO http://www.who.org		IRPA http://www.irpa.net
PAHO http://www.paho.org		ISO http://www.iso.org
FAO http://www.fao.org		

In particular, the committee has regularly evaluated evidence for radiation induced health effects from studies of Japanese atomic bomb survivors and other exposed groups. Together with reviews of relevant animal and laboratory studies, these assessments have provided the foundation ICRP draws upon to develop its recommendations on radiation protection and to formulate international radiation protection standards. UNSCEAR's secondary functions include:

- Recommending appropriate measurement standards for its purposes;
- Identifying research needs;
- Sending experts on request to countries concerned about the impacts of nuclear weapons testing.

4.2. International Atomic Energy Agency (IAEA)

The IAEA was created in 1957 in response to expectations and fears arising from the utilization of nuclear energy. In the context of the international system of radiological protection, the IAEA plays a special role by establishing international standards. This role is specified in Article III.6 of the Agency's statute:

> "To establish or adopt, in consultation and, where appropriate, in collaboration with the competent organs of the United Nations and with the specialised agencies concerned, standards of safety for protection of health and minimisation of danger to life and property (including such standards for labour conditions), and to provide for the application of these standards to its own operation as well as to the operations making use of materials, services, equipment, facilities, and information made available by the Agency or at its request or under its control or supervision; and to provide for the application of these standards, at the request of the parties, to operations under any bilateral or multilateral arrangements, or, at the request of a State, to any of that State's activities in the field of atomic energy."

The IAEA safety standards are designed to facilitate the achievement of the fundamental safety objective of protecting people — individually and collectively — and the environment, without unduly limiting the operation of facilities or conduct of activities that give rise to radiation risks. To ensure that facilities are operated and activities conducted in a manner that reaches the highest standards of safety that can reasonably be achieved, measures have to be taken:

- To control radiation exposure to people and the release of radioactive material to the environment;

- To restrict the likelihood of events that might lead to loss of control over a nuclear reactor core, nuclear chain reaction, radioactive source or any other source of radiation;
- To mitigate the consequences of such events in case they occur.

4.3. International Labour Organization (ILO)

Standard setting is one of ILO's major means of action to improve living and working conditions worldwide. ILO standards are adopted as conventions and recommendations by the International Labour Conference. Among these is convention No. 115, which deals specifically with protection of workers against ionizing radiation. The ILO used the International Basic Safety Standards (Safety Series No. 115) (BSS) and the ICRP recommendations as a basis for application of the convention by those Member States which had ratified it. The current BSS was approved and cosponsored by six international organizations including the ILO. The ILO — together with international organizations of employers and workers — is collaborating with the IAEA and other organizations to revise the current BSS, verifying its full consistency with ILO recommendations and requirements.

4.4. World Health Organization (WHO)

The mandate of WHO regarding protection against ionizing radiation lies in the development and promotion of evidence based public health policies for its 193 Member States, with the aim of protecting human health and reducing risks from overexposure to radiation from any origin. Under International Health Regulations and Emergency Conventions, WHO has a mandate to provide medical assistance and public health advice in the event of radiological accidents or nuclear emergencies. WHO's functions in the field of radiation protection and health include stimulating the generation and dissemination of knowledge; providing evidence based guidance; raising awareness of potential health risks; advocating safe and rational uses of ionizing radiation; building capacities and providing technical assistance and information in support of its Member States' national programmes.

4.5. Pan American Health Organization (PAHO)

PAHO is an international public health agency with more than 100 years of experience in working to improve health and living standards in countries belonging to the Americas. It serves as a specialized organization for health within the Inter-American System. It also serves as WHO's regional office for the

Americas, and enjoys international recognition as part of the United Nations system. PAHO Member States include all 35 countries in the Americas; Puerto Rico is an Associate Member. France, the Kingdom of the Netherlands, and the United Kingdom of Great Britain and Northern Ireland are participating states, and Portugal and Spain are observer states. PAHO, as a regional office of WHO, has inter alia the following main duties regarding radiological health:

- To promote the proper planning and organization of radiation medical services in the health care system to improve equity, efficacy, efficiency and safety;
- To advise on the incorporation and utilization of appropriate technologies in the areas of diagnostic imaging and radiotherapy for the provision of comprehensive health services;
- To promote QA programmes in the areas of diagnostic imaging, radiotherapy and radiation protection;
- To advise governments on regulations/legislation for protection against undesirable effects of radiation;
- To support the design, organization, execution and evaluation of comprehensive education programmes and specific training activities for professional and technical personnel in the field of radiological health.

4.6. Food and Agriculture Organization of the United Nations (FAO)

FAO is a specialized agency of the United Nations, accountable to the FAO conference of member governments.

FAO has a mandate in radiation protection through the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. Its functions are:

- To assist FAO Member States in effectively responding to nuclear emergencies affecting food and agriculture through the development, coordination and implementation of agricultural countermeasures;
- To elaborate provisions of the Basic Safety Standards relating to nuclear or radiological emergencies affecting agriculture, including consideration of the Joint FAO/WHO Codex Guideline Levels for Radionuclides in Foods Contaminated Following a Nuclear or Radiological Emergency for Use in International Trade;
- To participate in interagency management arrangements, including the Joint Radiation Emergency Management Plan (EPR-JPLAN) of the international organizations.

4.7. European Commission

The Euratom Treaty (promulgated in 1957) allows for the development of nuclear energy while protecting the health and safety of workers and members of the public. Article 2 (b) of the treaty establishing the European Atomic Energy Community (Euratom Treaty) stipulates that "in order to perform its task, the Community shall, as provided for in this Treaty, establish uniform safety standards to protect the health of workers and of the general public and ensure that they are applied".

In particular, the European Atomic Energy Community (Euratom) has established basic safety standards for the protection of workers' health and the general public against dangers arising from ionising radiation, known as the European BSS Directive.[*] It is a legislative act addressed to the Member States of Euratom.

The Euratom Treaty also confers important responsibilities on the European Commission in terms of monitoring environmental radioactivity, and there is an important Euratom Research Programme.

4.8. The NEA Committee on Radiation Protection and Public Health (CRPPH)

Under the responsibility of the NEA Steering Committee, the Committee on Radiation Protection and Public Health (CRPPH) contributes to the adoption and maintenance of high standards of protection for workers, members of the public and the environment, supporting its members through its mandate, which is:

- To provide a high level forum for exchange of information and transfer of experience;
- To seek international understanding and guidance regarding interpretation and implementation of the ICRP recommendations and other international RP standards, and to contribute to the development of harmonised positions in this field;
- To advance concepts and policies which make the system of radiation protection more simple, transparent and adaptable to the broader social dimensions of decision making in complex radiological situations;

[*] Council Directive 96/29/EURATOM of 13 May 1996 Laying Down Basic Safety Standards for the Protection of the Health of Workers and the General Public Against the Dangers Arising from Ionising Radiation.

- To keep under review and to contribute to advancement of the state of the art in radiation protection science and technology;
- To promote international cooperative projects.

5. EXAMPLES OF COOPERATION AND COLLABORATION

5.1. Development of safety standards — co-sponsorship

Based on its statute, the IAEA has issued many standards on radiation protection, the International Basic Safety Standards (BSS) being among those having the most impact worldwide. The IAEA Board of Governors first approved the Basic Safety Standards for Radiation Protection in June 1962. They were first revised in 1967. The latest revision was published in 1996 as Safety Series No. 115, which was jointly sponsored by the FAO, the IAEA, the ILO, the OECD/NEA, PAHO and WHO. After an extensive review of the current BSS, a process to revise the standards was agreed upon both by IAEA Member States at their General Conference 2006 (GC(50)/RES/(10)2006) and by BSS cosponsoring organizations.

To accomplish this revision, the sponsoring organisations established a joint secretariat for the preparation of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (standards). The joint secretariat — coordinated by the IAEA — has the overall responsibility for revision of the BSS.

The new standards will supersede the previous BSS and will reflect current knowledge and developments in radiological protection, safety and related fields. They will be based on experience in implementation, on new scientific data and on the new ICRP recommendations. The new version of the International Basic Safety Standards is expected to be approved by all cosponsoring organizations, through their own institutional mechanisms, within the timeframe 2010 to 2011.

Entities which did not sponsor the existing BSS but which envisage cosponsoring the new International Basic Safety Standards on radiation protection include the EC and the United Nations Environment Programme (UNEP). Both are involved in ongoing work on its revision.

5.2. Importance of co-sponsorship

Co-sponsorship of safety standards strengthens their relevance in that each of the cosponsors is expected to use the safety standards as a basis for their work and for advising Member States.

Co-sponsorship provides the opportunity for cosponsoring organizations to be fully integrated into development of the safety standards and into any further review and revision of a safety standard they previously cosponsored. Cosponsoring organizations should exchange information in relation to the need for development or review and revision of safety standards, and on their experience in application of the safety standards.

Other examples of cosponsored standards include:

- Safety requirements entitled Preparedness and Response for a Nuclear or Radiological Emergency, jointly sponsored by seven international organizations and published in 2002;
- A safety guide entitled Arrangements for Preparedness for a Nuclear or Radiological Emergency, jointly sponsored by six international organizations and published in 2007;
- Safety fundamentals entitled Fundamental Safety Principles, SF-1, published in 2006 and jointly sponsored by nine organizations;
- Safety Requirements for Geological Disposal of Radioactive Waste, published in 2006 and jointly sponsored by two organizations.

Another way that members of the IACRS cooperate on topical radiation protection issues of common interest is through the establishment of ad-hoc working groups. This has been the case regarding investigation of radiation protection and the public health aspects of security screening using ionizing radiation.

6. KEY CHALLENGES

International bodies need to provide consistent advice and assistance to the various governmental agencies of their Member States. To achieve this, they will need:

- To develop broad agreement, through discussions among IACRS member organisations, concerning consistent interpretation of the precautionary principle as it applies to specific cases (e.g. radon, worker protection, environmental protection, protection of people collectively and of future generations, etc.) and to facilitate its harmonious implementation;
- To develop and improve effective networking processes and procedures to help ensure consistent and coherent international approaches to radiation protection issues;
- To continue to identify areas for interagency cooperation and collaboration.

EMERGING CHALLENGES IN THE MANAGEMENT OF MEDICAL EXPOSURES

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Abstract

The use of radiation in medicine produces major benefits in terms of the diagnosis and treatment of human diseases. Today, the world is going through a period of major technological changes in the fields of imaging and radiotherapy. Medical use of ionizing radiation has become by far the largest artificial source of radiation exposure. The impact of the doses of radiation that the future population of the world will receive is very difficult to predict. The application of International Standards and the System of Radiation Protection is necessary to protect and assure patient safety. The involvement of health authorities and medical professional societies is essential to effectively implement such standards. The challenges are enormous and require strategic partnerships among the many stakeholders.

1. INTRODUCTION

Medicine was revolutionized at the end of the 19th century thanks to a number of discoveries in the field of physics which have been incorporated to better the diagnosis and treatment of human diseases. The beneficial effects of these technological advances for public health are substantial. Diagnostic radiology (basic and specialized), image guided interventional radiology, diagnostic and therapeutic nuclear medicine, and radiation therapy are currently playing an essential function both in clinical health care and research.

Medical applications of ionizing radiation involve all types of exposures: public, occupational and medical. However, medical exposure refers only to the exposure incurred by patients for the purposes of medical or dental diagnosis or treatment; by caregivers and comforters; and by volunteers in biomedical research programme involving their exposure. The non-medical imaging of humans, such as exists for security or theft detection purposes, does not belong to any of the medical exposure categories, although radiation is also intentionally delivered to human beings.

Uncertainties involved in cancer risk estimates related to low doses of radiation still exist. Nevertheless, the inability to detect increases in radiation induced cancer at very low doses does not mean that risk does not exist.

2. MEDICAL EXPOSURE

Medical exposure is by far the largest radiation source affecting human beings, aside from natural background exposure, and is increasing considerably. Current estimations by UNSCEAR of the global annual effective per caput dose reflect a significant increase in medical exposure over the last decade. As a consequence, medical exposure has become a public health concern.

However, variations in medical exposure between countries, and even between regions of a country, can be considerable. The global dose per caput increase is mainly due to contributions by countries with level I and II health care, while in countries with level III health care this increase has not been noted and in level IV health care countries it has even decreased. In some high income countries, medical exposure is currently even higher than exposure from natural sources for the first time in the history of human beings. This fact illustrates the enormous inequity and heterogeneity in medical use among countries, which has to be considered when addressing this issue on a global perspective.

2.1. Health technologies considerations

Today, the world is going through a period of major technological change in the fields of imaging and radiotherapy. These technological advances are changing radiation doses per medical procedure. In some cases — such as mammography — the average dose per procedure has decreased due to new technological developments in the system of radiation detection. However, in many others — such as computed tomography (CT) — there has been an important increase. There has also been a change in the pattern of medical exploration in which the proportion of children and young people, who are likely to be at higher cancer risk from radiation than adults, is increasing.

Acquiring images through digital radiology could lead to the unnecessary exposure of patients to radiation if appropriate training and precautions are not observed. Over the past decades, CT has had fast and widespread use for clinical and screening purposes. New technology has developed from conventional CT to multidetector CT, with a resulting higher exploration frequency and wider scan volumes that increase patient dose per scan. Today, CT has become the most important contributor to medical exposure in diagnostic radiology.

New complex and long interventional image guided procedures have been introduced worldwide and continue to expand. Benefits are immense; it is now possible to treat some medical conditions that once required very complex surgery using minimally invasive techniques. However, radiation doses delivered during such procedures can be high enough to go beyond the threshold for deterministic effects.

Hybrid imaging modalities are also being rapidly incorporated worldwide. Radionuclide tracer techniques such as positron–emission tomography (PET) and single photon emission computed tomography (SPECT) can now be fused with CT, combining good image quality with functional information. These procedures may involve important levels of radiation and therefore imply new challenges for radiation safety. The use of nuclear medicine for therapeutic purposes is no longer limited to the treatment of thyroid diseases and bone metastases. In the last few years, potential applications of therapeutic radiopharmaceuticals have expanded, and new tumour targeting methods have been developed.

Complex radiotherapy techniques such as intensity modulated radiotherapy (IMRT), which increases integral patient dose dramatically compared to conventional or conformal radiotherapy, and image guide radiotherapy (IGRT), are also being introduced worldwide. An important number of overexposures — both in industrialized and developing countries — have occurred in patients undergoing radiotherapy, some of which resulted in severe health consequences and even deaths, causing boundless concern among health authorities, regulatory bodies, the medical community, patients and the general public.

All these changes, coupled with an increase in the amount of medical radiation equipment worldwide, will have significant repercussions on the doses of radiation that the population receives, making it important for health authorities and regulatory bodies to continue assessing protection and safety regarding medical exposures.

2.2. Application of the system of radiation protection to medical exposures

2.2.1. International standards

The potential health risk that the use of radiation implies makes it necessary to take special precautions to protect patients. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), currently undergoing revision, covers and specifically addresses radiation safety in medical exposures. However, BSS implementation is far from complete in many countries, especially requirements for medical exposure, thus making it the least regulated type of radiation exposure.

Each country has different needs for harmonization and for the implementation of BSS requirements for medical exposure. Intergovernmental organization cosponsors of the BSS are well aware of that situation. To address this circumstance, technical cooperation should be focused on pending issues in priority countries, as well as protecting their achievements without forgetting pending issues, on looking at new challenges in intermediate countries, and on new challenges in highly developed countries.

2.2.2. Justification

Justification is probably the most important radiation protection principle to deal with regarding medical exposures. The justification of a generic procedure that involves medical exposure is the responsibility of health authorities and medical professional societies, while justification of a procedure on an individual is mainly a matter of the referring medical practitioner and the radiological medical practitioner, who has the overall responsibility.

The availability and use of referral guidelines and appropriateness criteria, developed on evidence based medicine, are the main tools for applying the principle of justification for medical exposures. These tools need to pay particular attention to pregnant, breastfeeding and paediatric patients. As for opportunistic screening, health authorities should be able to control and influence the process through policies and assure that the patient is informed about benefits, risks and limitations of a particular procedure.

2.2.3. Optimization

The implementation of a quality assurance (QA) programme is essential with respect to optimization of doses delivered to patients. Availability and access to properly qualified medical physicists are crucial to implementation of a QA programme. A medical physicist must perform appropriate tests at the time of acceptance and commissioning of any new equipment or technique, execute or supervise quality control (QC) tests periodically and after any major maintenance intervention, and calculate clinical dosimetry, as required.

However, the increasing complexity of treatment and diagnostic imaging technology, the expectations of better health care, and the implementation of more stringent radiation safety standards and professional certification requirements are worsening an already critical shortage of clinically competent medical physicists worldwide, making the situation critical in low and middle income countries. As for the possibility of educating more medical physicists, the reality is that while some countries have formal educational programmes for these professionals (albeit sometimes with poor curricula), in some other small or poor countries, the very low number does not permit educational programmes at a country level.

2.2.4. Dose limits

Unlike public and occupational exposures, in medical exposure too little or too much of a dose is bad both for diagnosis and therapy. As a consequence, dose limits do not apply to medical exposures.

However, for diagnostic applications there is a need for the establishment of Diagnostic Reference Levels (DRL) as dynamic values, which would be tools for the optimization process. Additionally, for caregivers and comforters as well as for volunteers in biomedical research, dose constraints rather than limits are needed. These requirements for DRL and dose constraints must be locally or nationally established through consultation between health authorities, medical professional societies and regulatory bodies.

2.3. Summary of challenges in medical exposures

New and rapidly evolving health technologies raise new radiation protection issues which must be addressed. There must be a system of continuous assessment for the radiation protection status of medical exposures.

Effective implementation of BBS medical exposure requirements worldwide is a complex task. The availability and use of referral guidelines and appropriateness criteria are key tools for justification of medical exposures, while the implementation of QA programmes is essential to optimize radiation doses and assure radiation safety for patients.

The existence of minimally trained staff jeopardizes patient safety and even lives. There is also a shortage of qualified personnel, particularly medical physicists. Health professionals involved in the processes of referring, diagnosing or treating patients should be properly and regularly trained in radiation protection.

Countries should introduce, apply and monitor the implementation of appropriate regulations. The regulatory body could include more than one body at the country level, each having different responsibilities. Health authorities and medical professional societies must participate in the regulation of medical exposures. International organizations should raise awareness of health authorities and public health officials regarding the needs and challenges we face in applying these health technologies. There must be a closer relationship between the regulatory body and health authorities.

Harmonization and better coordination among multiple stakeholders are needed. The work remaining is enormous and strategic alliances among international organizations, specialized institutions, professional bodies, scientific societies and academic institutions are of key importance.

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EMERGING CHALLENGES IN THE MANAGEMENT OF OCCUPATIONAL EXPOSURES

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Abstract

The paper outlines key challenges for the future from the perspective of constituent parties of regulatory bodies, workers, employers and the IAEA and ILO. A key theme is the need to ensure the establishment and implementation of harmonised international policies, standards and guidance in the field of occupational radiation protection, and the close involvement of workers and employers and their organizations in reaching that goal. All parties recognize that there has been improvement in the level of protection and safety of occupationally exposed workers in many areas of work with ionising radiation but that this is largely in countries with well developed regulatory and operational infrastructure utilising sources of ionising radiation.

Increasingly, the development of new techniques and use of ionising radiation in both the medical arena and for energy generation to meet societal needs presents challenges to all involved parties. The ILO — in collaboration with other international organizations — seeks global promotion of the basic principles for radiation protection of workers embodied in the Radiation Protection Convention (No. 115) in both developed and developing nations.

1. BACKGROUND INTRODUCTION

Protection of the worker against sickness, disease and injury arising out of employment is one of the tasks assigned to the ILO in the preamble of its constitution. The development of international standards in the form of conventions and recommendations is one of the main functions of the ILO. As a package, they constitute the International Labour Code, which defines minimum standards in the labour and social fields. Between 1919 and 2008, 188 conventions and 199 recommendations were adopted. Close to 50 per cent of these instruments relate directly or indirectly to occupational safety and health; among them Convention No. 115 and Recommendation No. 114, which deal specifically with the protection of workers against radiation (ionizing).

Convention No. 115 applies to all activities involving exposure of workers to ionizing radiations in the course of their work and provides that each member of the ILO who ratifies it shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate methods. Fourty-eight countries have ratified it. The convention and recommendation lay down basic principles and establish a fundamental framework for radiation protection of workers. They also contain provisions about protective measures to be taken, the monitoring of radiation and the medical supervision of workers.

The general principles that apply to occupational radiation protection include the following:

— Workers who are neither engaged in radiation work (i.e. who are not exposed to radiation sources which are directly related to their work or required by their work) nor engaged in work activities that involve or may involve exposure to radiations higher than public exposure should receive the same level of protection as members of the public and are subject to the general radiation protection regulatory system which applies to members of the public;
— Workers who are engaged in work with radiation sources (radiation workers), emergency workers involved in a rescue or in a remedial action after a radiological accident, and workers engaged in work activity involving exposure or potential exposure higher than public exposure should receive an appropriate level of protection governed by the occupational radiation protection regulatory system. Protection of the public and occupationally exposed workers is an integral part of the radiation protection regulatory system as a whole.

Conventions are comparable to multilateral international treaties; they are open to ratification by Member States and, once ratified, become binding

obligations. ILO standards have exerted considerable influence on the laws and regulations of Member States. Many texts have been modelled on the relevant provisions of ILO instruments. Drafts of new legislation or amendments are often prepared with ILO standards in mind so as to ensure compliance with ratified conventions or to permit ratification of other conventions. Trade unions use ILO standards to support arguments in bargaining and in promoting legislation. Governments frequently consult the ILO, both formally and informally, about the compatibility of proposed legislative texts with international labour standards.

In 1987, the ILO published a code of practice on radiation protection. Subsequently, and with a view to establishing basic requirements for protection against risks associated with exposure to ionizing radiation and for the safety of radiation sources that may deliver such exposure, six international organizations (FAO, IAEA, ILO, OECD/NEA, PAHO, WHO) jointly developed and cosponsored the International Basic Safety Standards for Protection against Radiation and for the Safety of Radiation Sources (BSS). These standards were published by the IAEA in 1996 and represent unified guidance and 'the' requirements of the UN system concerning radiation protection because they are common to the six sponsoring organizations.

The BSS is currently being updated and revised. ILO participation was approved by its governing body at its 298th session in March 2007 (ILO GB.298/15/2). The ILO governing body also nominated employers' and workers' experts to participate in revision of the BSS alongside the office.

There are a number of international instruments that establish the general framework and institutional arrangements for the protection of workers against occupational hazards in general. They are also relevant to the radiation protection of workers. For example, the Occupational Safety and Health Convention No. 155 and Recommendation No. 164 concerning occupational safety and health and the working environment lay down for the first time at the international level the foundations of a national policy branching out to undertakings, in order to introduce a comprehensive and coherent system of prevention of occupational hazards. Convention No. 161 and Recommendation No. 171 concerning occupational health services provide for the establishment of occupational health services which should progressively be developed for all workers in all branches of economic activities. These instruments cover, in particular, the functions, organization and conditions of operation of such services.

The ILO is committed to international cooperation to promote effective and internationally harmonized occupational radiation protection standards and the wider application of the (international) Radiation Protection Convention of 1960 (No. 115). Such cooperation at the international level is also the expectation of Member States. For example, the 46th General Conference of the IAEA adopted a Resolution that "requests the Director General (of the IAEA) to look into the

possibility of the IAEA cooperating with the International Labour Organization and other relevant bodies in formulating and implementing, subject to the availability of resources, an international action plan for occupational radiation protection……." (GC(46)/RES/9 Sept 2002).

An International Action Plan for Occupational Radiation Protection prepared by the IAEA in collaboration with the ILO was approved by the 47th IAEA General Conference in 2003. It is worth noting that the Action Plan for Occupational Radiation Protection places the ILO Radiation Protection Convention of 1960 (No 115) in focus and places BSS requirements on occupational exposure within the perspective of the implementation of the convention's provisions. The Action Plan for Occupational Radiation Protection is currently being implemented by the IAEA in collaboration with the ILO and with participation by the IOE and ITUC.

To assist countries in designing and implementing national programmes and activities for occupational radiation protection, it is important for international organizations to promote internationally recognized good practices, including international standards, by using in a coordinated manner the various means of action available to them to give governments, employers' and workers' organizations the necessary help in drawing up and implementing programmes for the improvement of occupational radiation protection.

2. CHALLENGES EMERGING OVER THE YEARS IN THE MANAGEMENT OF OCCUPATIONAL EXPOSURES

Member States and ILO constituents need harmonized international policy, standards and guidance on occupational radiation protection. The demands and expectations of Member States for international organizations to fulfil their roles and mandates in these regards are high. The challenges to meet these demands and expectations are enormous.

Occupational radiation protection involves in particular regulatory bodies, employers, workers, and radiation protection professionals. Their concerns and expectations for the management of occupational exposures are major challenges for international organizations that have mandates on occupational radiation protection. This paper has summarised these challenges from the perspective of regulators, workers, employers, the IAEA and ILO.

2.1. Regulators' perspective

Member State regulators at the 20th Session of the Radiation Safety Standards Committee in April 2006 discussed their concerns and expectations on

occupational radiation protection in relation to revision of the BSS, and identified the following issues to be addressed:

2.1.1. Pregnancy

Difference of dose requirements for both woman and foetus. The requirements should be amended to include:

- Dose limitation: The need to identify the problem of dose received between real and declared dates of pregnancy;
- Intakes: it is necessary to review the question of existing incorporations;
- The need to identify the necessity of specific monitoring of the foetus from the beginning of pregnancy onwards;
- If necessary, special monitoring into the breastfeeding period.

2.1.2. Genetic susceptibility

Tests will be probably available in the near future to screen for cancer susceptibility. This is an issue for workers' rights.

2.1.3. Gender susceptibility

There is a need to handle the consequences of differences between men and women with regard to susceptibility to radiation induced cancer, and how this could be addressed in requirements.

2.1.4. DDREF

This issue is relevant to workers receiving the highest doses. Is the current value of 2 acceptable?

- In principle, the BSS dose limits are acceptable at present.
- Is it necessary to revise the intervention level for emergency teams?
- Is the working lifetime dose limit acceptable?

2.1.5. Dose limits for emergencies

Is there a need to revise the dose limits for emergency workers? Is there a need to consider non-cancerous effects such as cardiovascular diseases?

2.1.6. Dose to the eye lens

New evidence shows that the difference between the limit and the threshold dose for the formation of cataracts is not acceptable. Dose limit to the lens should be reviewed.

2.1.7. Radon at work

Workers are exposed to high concentrations of radon and progeny in water works, for example, or caves. This can lead to annual doses above 50 mSv. As a consequence, the requirements in this area should be more stringent. The BSS DCFs for radon and progeny should be reviewed.

2.1.8. Definition of occupationally exposed workers

Both natural and artificial radiation has to be considered, if the annual dose exceeds 1mSv; requirements need to be unified. Specific requirements need to be developed for practices, facilities and exposure situations.

2.1.9. Terminology

Consideration needs to be given to harmonization and stability. For example:

- Sources and Practices (BSS);
- Facilities and Activities (GS-R-1);
- Exposure Situations (ICRP- existing, planned, emergency).

2.1.10. Quality management

The requirements as to quality management systems in view of harmonization of reported doses, especially for itinerant workers need to be reviewed.

2.1.11. Minimum requirements for service providers

Should minimum requirements for service providers be established?

2.1.12. Qualified experts and radiation protection officers

What are their roles, responsibilities and qualifications?

2.1.13. Classification of areas

More practical guidance is needed on how to define these areas.

2.1.14. Air crew exposure

Should the requirements include air crew exposure?

2.2. Workers' perspective

There are currently many challenges in ensuring adequate safety in the workplace consistently around the globe. There is definitely uneven implementation of all safety standards whether these are radiation protection or industrial safety standards between different geographical areas depending on the technological and economic levels of the area.

It is perverse to observe that multinational companies tolerate or even ignore unsafe working practices in some parts of the world that would be completely unacceptable and illegal in their home country.

The paramount objective for workers is the actual implementation of safety standards, whether these are harmonised across the world or not. When and only when establishment and adherence to safety standards becomes embedded at the work place can harmonization of standards can be considered and progress.

Therefore, as part of the existing challenge of implementing safety standards at every workplace, there are also at present significant challenges in the management of occupational exposure from mining, industrial radiography, and even from the benign use of radiation in medical applications. Some of these challenges arise from lack of knowledge and poor understanding of the risks of radiation, eagerness to make use of the most up to date medical advances without the necessary infrastructure being in place, lack of training and equipment, and some arise from a poor safety culture and even exploitation of workers.

Therefore, the biggest challenge in the management of occupational exposure is the recognition that occupational exposure is a safety issue and radiation is a hazard that needs to be managed. It needs to be recognised that it is a hazard not only in nuclear power plants in developed countries, but it is a hazard wherever radiation is being used as a tool or even as a medicine.

These challenges will continue to be exacerbated by continuous technological improvements making the gap between technologically advanced geographical areas and not advanced areas bigger; this gap can exist even within a single country between urban and rural areas!

The role of interagency bodies is to promote safety standards and most importantly the implementation of these safety standards. However, in addition to

their work on safety standards, and maybe an even more important aspect of their work, are interagency initiatives aimed at increasing the basic level of safety for workers. In the arena of occupational exposure an example is the Action Plan for Occupational Radiation Protection. Initiatives like these work at different levels:

- By promoting the adoption of international safety conventions and standards by governments;
- By providing tools for promoting safety such as training, and visual aids such as safety leaflets and posters, educational material etc.;
- By encouraging the application of safety standards either through direct or indirect means or through the exchange of information and practices.

2.3. Employers' perspective

The latest ICRP recommendations present an opportunity to develop workable and realistic harmonised standards for radiological protection. Over the years, through the development of standards, there have been improved levels of protection for all workers, members of the public and the environment. Whilst there are no fundamental changes to the basis of protection standards, the challenge is to seek a common understanding and implementation of those existing.

Challenges are presented by the decommissioning of older nuclear facilities which may not have been designed with easy decommissioning in mind, whilst at the same time there is renewed interest in the provision of nuclear power and new technologies. It is important that the ALARA principle is met through realistic and effective radiological protection programmes in all aspects of work. In general, exposure to ionising radiation has shown a downward trend over many years, but there is the potential that exposures may increase as legacy issues are dealt with. While there is a need to recognise that exposures may increase the key principle is to ensure that all exposures in all situations are maintained as low as practicable. There is an increasing need to manage disused radioactive sources and there is a challenge for greater international cooperation.

It is important as harmonization of standards progresses that radiation protection be seen as an integral part of sound and effective health and safety management systems and not be considered in isolation. Too often radiation protection is seen as a specialized area, when the fundamentals of good health and safety management are just as applicable.

A qualified expert is a fundamental component of safety standards, and it is important that training and education programmes meet the needs of personnel involved in the operational implementation of radiation protection. There is a need to maintain and develop expertise and competence in the field of radiation

protection and particularly to encourage young people to follow a career in this discipline.

As technology develops, it is important that methodologies for dose assessment meet requirements and are developed and improved. Greater development of electronic dosimeters and continued refinement of internal dose models are important to ensure realistic dose assessments for workers are made.

More lessons could be learned from 'events' in terms of operational learning experience.

2.4. IAEA's perspective

Although the level of protection and safety of occupationally exposed workers has significantly increased in many practices using or producing ionizing radiations, this improvement is mainly measurable in the nuclear fuel cycle and in countries having developed nuclear programmes for many years.

As a matter of fact, the occupational radiation protection of workers is still facing many challenges for existing practices and the next years will undoubtedly confirm this statement.

Indeed, radiation protection of medical workers may not yet been considered to be always complying with basic requirements as developed for example by the IAEA. Other applications of ionizing radiations, such as in industrial radiography, show that the implementation of these requirements is also far from being fully achieved. Moreover, lack of information on exposure in the use of ionizing radiation for research purposes (fuel cycle, radiopharmaceuticals, etc.) doesn't allow for a clear view of the present status of radiation protection in these areas. These challenges are now recognized in many developed countries and improvements can be expected in the coming years. Through the new Information System on Exposure in Medical-, Industrial- and Research areas, the Agency intends to collect relevant information and develop additional guidance to improve radiation protection and safety in these areas.

It is also becoming clear that many developed or developing countries plan to embark in the use of new technologies in medical areas and/or in the production of energy based on the nuclear fuel cycle. In order to ensure that these new practices are performed safely, these countries should be strongly encouraged to implement the basic requirements on safety and radiation protection. In particular, for occupationally exposed workers, the development of a regulatory infrastructure as well as availability of adequate service providers should be considered a priority. Knowledge transfer and sharing of experience should be considered very important tools for establishing a high level of safety for these new practices.

Last but not least, greater attention needs to be paid to the protection of so-called ‘itinerant workers’ — sometimes also identified as ‘contractors’ or ‘external workers’. Indeed, due to the inherent mobility of workers belonging to this category and to the large diversity of workplaces in which they are employed, attribution of legal responsibilities and precise description of the means to be used for ensuring their protection require specific focus.

ILO and the IAEA — through the joined secretariat of the International Action Plan on Occupational Radiation Protection for example and in cooperation with other international institutions — should maintain their efforts to provide guidance and technical support with the aim of ensuring the welfare of workers in the workplace.

2.5. ILO’s perspective

Issues of particular concern to the ILO relate to the responsibilities of the employer, the role of the competent authority, and workers' rights and obligations. The challenge is how to better embody provisions in the convention for the Protection of Workers against Ionising Radiations (No. 115) and its accompanying recommendation (No. 114) in all of ILO’s 183 Member States. In particular:

Article 3

1. In the light of knowledge available at the time, all appropriate steps shall be taken to ensure effective protection of workers, as regards their health and safety, against ionising radiations;
2. Rules and measures necessary for this purpose shall be adopted, and data essential for effective protection shall be made available.

Article 5

Every effort shall be made to restrict the exposure of workers to ionising radiations to the lowest practicable level, and any unnecessary exposure shall be avoided by all parties concerned.

Article 6

1. Maximum permissible doses of ionising radiations which may be received from sources external to or internal to the body and maximum permissible amounts of radioactive substances which can be taken into the body shall be fixed in accordance with Part I of this Convention for various categories of workers;
2. Such maximum permissible doses and amounts shall be kept under constant review in the light of current knowledge.

Article 7

1. Appropriate levels shall be fixed in accordance with Article 6 for workers who are directly engaged in radiation work and are:
(a) aged 18 and over;
(b) under the age of 18.
2. No worker under the age of 16 shall be engaged in work involving ionising radiations.

Article 8

Appropriate levels shall be fixed in accordance with Article 6 for workers who are not directly engaged in radiation work, but who remain or pass where they may be exposed to ionising radiations or radioactive substances.

Article 9

1. Appropriate warnings shall be used to indicate the presence of hazards from ionising radiations. Any information necessary in this connection shall be supplied to the workers;
2. All workers directly engaged in radiation work shall be adequately instructed, before and during such employment, in the precautions to be taken for their protection, as regards their health and safety, and the reasons therefore.

Article 10

Laws or regulations shall require the notification in a manner prescribed thereby of work involving exposure of workers to ionising radiations in the course of their work.

Article 11

Appropriate monitoring of workers and places of work shall be carried out in order to measure the exposure of workers to ionising radiations and radioactive substances, with a view to ascertaining that the applicable levels are respected.

EMERGING CHALLENGES IN THE MANAGEMENT OF PUBLIC AND EMERGENCY EXPOSURE

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Abstract

The direction of radiological protection thinking has been developing and evolving since the very beginning of the ICRP in 1928. This evolution has been both episodic (e.g. new risk factors from epidemiology studies) and continuous (changing social values, gaining experience in implementing radiological protection) and provides us with significant historical backup. This historical perspective puts us in a good position to assess current challenges in the areas of public and emergency exposure management. In public exposure, challenges include adapting to increasing stakeholder involvement in decision making processes, the management of radon exposure, and integrating new and emerging scientific knowledge into radiation protection practice. In emergency management, challenges include the incorporation of stakeholder input into consequence management, developing approaches to optimisation of protection strategies, and better understanding of objectives and processes for recovery.

1. INTRODUCTION

The direction of radiological protection thinking has been developing and evolving since the very beginning of the ICRP in 1928. While significant changes have occurred following new scientific results (e.g. new risk factors from epidemiology studies) or regarding addressing new risks within the system (e.g. emergency management or radon), social values and experience at implementing radiological protection have evolved in a more continuous fashion. Thus radiological protection principles, policies, standards and regulations are the result of a continuum of incremental enhancement, incorporating state of the art scientific developments, evolving social values, international developments and lessons learned through implementation of the system of protection.

From this perspective we can ask, what are the key challenges for the future in terms of managing public and emergency exposures?

2. HISTORICAL LEGACY

The historical legacy from which we must view radiological protection is rooted in social values. The nature of radiological protection is the search for the most appropriate level of protection under prevailing circumstances. This implies the most scientifically well founded assessment of risk, the most complete assessment of protection options, and a judgement regarding what decision should be taken.

Throughout development of the system of radiological protection, principles have been adjusted to appropriately address considerations of:

- **Responsibility:** the justification principle;
- **Equity**: the limitation principle;
- **Precaution**: in the face of uncertainty — the optimization principle.

Thus, the three RP principles are part of the fabric of social existence, such that 'where we are going' can be most clearly seen from the perspective of 'where we came from'.

3. KEY CHALLENGES

As such, the general challenges facing the radiation protection community today are driven by social imperatives but have scientific roots. These broad challenges form the context in which challenges for the management of public and emergency exposures should be seen, and include:

- A growing need to more explicitly consider the balance between internationally agreed upon harmonized approaches to radiological protection, and locally driven case specific solutions;
- Applying the precautionary principle for optimising protection of the public (in 'normal' and emergency situations) requires increased transparency and stakeholder engagement in decision making;
- An increase in citizen vigilance, as a check and balance to governmental and regulatory decisions.

3.1. Public exposure challenges

In the particular area of public exposure, key challenges concern approaches to decision making and stakeholder engagement — particularly in situations where the public would be asked to accept some level of residual risk.

They also concern programme adjustments that may be necessary to best manage radon exposure in the light of new epidemiological results and difficulties with public engagement. Finally, they concern possible implications that new scientific results could have on the practical implementation of radiological protection principles. These most significant public exposure management challenges principally concern radon and 'situational exposures' that are tied specifically to particular activities. Some elaboration of these concerns is listed here:

- Evolution of structures and procedures for optimum engagement with stakeholders:
  - —Cleanup of contaminated areas and materials management
  - —Decommissioning and dismantling
  - —New nuclear installation siting (e.g. NPPs, waste sites)
- Management of public exposure to radon:
  - —Focus on distribution high end, or distribution average?
  - —New reference levels?
  - —Global approach to indoor air quality?
  - —Focus on specific groups at risk (e.g. children, pregnant women)?
- Integration of emerging science in the management of public exposures:
  - —New radon epidemiological evidence
  - —Bystander effects
  - —Cardiovascular diseases

3.2. Emergency exposure challenges

It is fair to say that the particular area of emergency exposures has been most significantly changed in the new ICRP recommendations. The ICRP Publication 60 approach of using practices and interventions, and of using intervention levels below which it was unlikely that actions would be justified, has been completely replaced by a system that focuses on optimisation of an overall protection strategy for all those exposed, and that uses reference levels as a planning guide and as an implementation benchmark. Knowing how this new system should be understood and reflected in standards and regulations will take some time.

It can also be said that our society now faces a broadening range of emergency situations, including RDD terrorist attacks for example, for which planning and preparedness are necessary. More generally, recovery from any emergency situation is increasingly recognised as requiring governmental commitment to engagement with stakeholders in defining recovery objectives and processes, and in planning and implementing recovery actions. Emergency

planning is increasingly viewed with an integrated approach, on which economics will have a significant impact.

Finally, it is clear that the past years of study and undertaking emergency exercises have generated many lessons that have yet to be fully internalised and implemented in emergency planning and preparedness approaches at national and international levels.

The topics listed are all well known, but are intended here to be seen in light of the previously listed 'Key Challenges'.

- The optimisation of a protection strategy focusing on residual dose must be studied, as recommended in ICRP 103;
- There is a need to prepare for a wide range of emergencies (e.g. RDDs);
- Stakeholder involvement in planning and late phase consequence management may challenge organizational structures and procedures;
- Further guidance is needed on objectives and processes for recovery;
- Further guidance is needed for a broad range of countermeasures, taking into account an expanding spectrum of decision making considerations;
- Many lessons learned are still to be implemented;
- Cross cutting issues include:
  —Long term social/technical aspects in decision framing
  —The impact of economics on decision making.

3.3. How to address these challenges

So, how should these challenges be addressed? Specifically, how can IACRS member organisations assist in moving forward? It is clear that IACRS organisations have broad and deep experience that can be harnessed to assist in addressing these issues. In spite of the fact that each country has its own structural and legal approach to addressing public and emergency exposures, the challenges that we all face have many commonalities that can very effectively be addressed at the international level in a generic fashion. Documented, broad agreement on the most appropriate way forward can serve as input to national level discussions to develop specific legislative and regulatory approaches to these important issues. As organisations joined together in an effort to best assist our members, we can work together to efficiently use the most relevant experience in leading efforts to address questions raised by our national members. In this way, resource use can be optimised at both international and national levels, and the broadest possible experience can be brought to bear on these challenging issues.

In other words, while the importance of international cooperation is clear, it must be recognised that problems are generally solved through national legislation. Even so, there is great efficiency to be gained through cooperation in

addressing common issues, sharing good practice, and focusing on effectively using the relative strengths of international organisations.

International organisations and their constituencies, building on their specific strengths, should continue to work together to collectively identify issues, commonalities, good practice and ways forward on:

- BSS development (IAEA, NEA, WHO, ILO, PAHO, FAO, UNEP, EC);
- Radon exposure management (WHO, NEA);
- Stakeholder engagement experience (NEA, ILO);
- International emergency exercises (NEA, IAEA, EC);
- International standards (IAEA, WHO, ILO, NEA);
- International Action Plans (IAEA).

Although national structures and approaches differ, the identification of commonalities and good practice can facilitate the development of national and international solutions.

BACKGROUND PLENARY SESSION IV

STAKEHOLDER ENGAGEMENT IN DECISION MAKING IN RADIOLOGICAL PROTECTION: IRPA GUIDING PRINCIPLES

Background Session IV addressed 'Stakeholder Involvement in Decision Making', as well as 'IRPA Guiding Principles'. It was chaired by Argentine Nuclear Regulatory Authority board of directors President Dr. Raul Racana, and featured presentations by the French Institute of Radioprotection and Nuclear Safety (IRSN) Director General Jacques Repussard, who presented the IRSN experience, and Tony Bandle (UK SRP), who described in his presentation the process of development and professional reasons behind IRPA's 'Guiding Principles Stakeholder Engagement in Decision Aiding in Radiological Protection' which are included in the next subchapter.

There are professional reasons to have these principles. Involving stakeholders appropriately whether they are other professionals or artisans like doctors, engineers, technicians and ecologists, or workers, the local community or the general public, should be an integral part of the radiological protection processes of justification and optimization.

Justification is about weighing benefits against costs, including wider considerations that are less tangible. In areas that affect people lives, their health, their wealth and their well being, or their environment, why not involve them? Optimization is about weighing options. Where these options significantly affect people or their environment, why not involve them? Attention to both of these fundamental principles of radiation protection in the context of stakeholder involvement leads to solutions which are more widely agreed upon and owned and are therefore more sustainable. This set of principles is not the output of academic studies or a wish list draw up by idealists; the principles represent the distillation of a huge amount of real life experience and lessons learned the hard way, fought over and debated by a representative group of radiation protection professionals, validated by actual stakeholders and which make reference to authoritative research. The guiding principles are intended to aid members of IRPA associate societies in promoting participation of all relevant parties in the process of reaching decisions involving radiological protection which may impact on the well being and quality of life of workers and members of the public, as well as the environment. In promoting this approach, radiological protection professionals aim to develop trust and credibility throughout the decision making process in order to improve the sustainability of any final decisions. IRPA12 attendees were asked to endeavour to make IRPA principles a daily reality.

STAKEHOLDER INVOLVEMENT. THE INSTITUTE OF RADIOPROTECTION AND NUCLEAR SAFETY EXPERIENCE

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Abstract

Cooperation between experts and people affected by radiation in any radiological accident situation, and more generally public trust in the institutions responsible for evaluation and management of radiological risks, is a key factor for developing efficient radiation protection policies and operations. However, cooperation and trust cannot simply be ordered, and where it has been damaged, or when it is lacking, its rebuilding or enhancement requires the support of a carefully planned process over a number of years. Since 2006, in agreement with the French government ministers overseeing IRSN's development, the institute has embarked on a policy of 'opening to society', aimed at 'bringing together the experts and the stakeholders'. Taking advantage of the modernisation of the national organization for nuclear safety and radiation protection — which has led to a multifaceted system in which the stakeholders are present, particularly in the 'local information committees' (CLI) set up at each nuclear site — IRSN has launched a strategy and an operational implementation programme which basically consists in 'investing in people'. This means people from within the institute itself, to bring about required culture changes, and also people outside the institute, through education, cooperation with CLI and stakeholder associations, and people in research bodies, to move towards more 'society oriented' R&D programmes, for example in order to reduce existing uncertainties in the field of low dose risks. This presentation thus illustrates the path initiated by IRSN, which has already brought about practical results, but which needs to be pursued over a long period in order to build a lasting capital of trust within society.

1. INTRODUCTION

Radiation protection is about people. People (workers, consumers, citizens) who need protection from a physical risk their senses cannot apprehend, and which they are not culturally equipped to deal with (understand spontaneously, in order to prevent or limit risk). Such protection must therefore be organised by 'experts', and be regulated by competent authorities, in accordance with state of the art knowledge. In advanced, so called 'knowledge based' societies, there is a growing tendency to question readymade solutions proposed to people. The

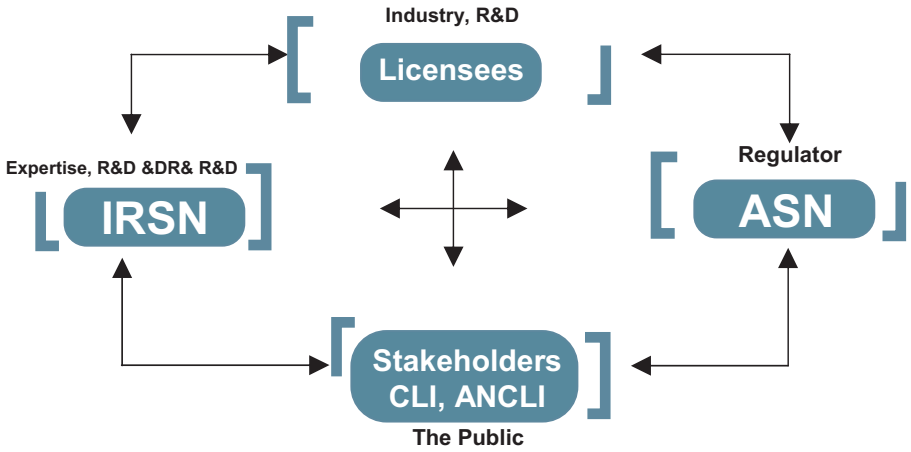

FIG. 1. The French multifaceted organization for civil nuclear safety and radiation protection.

historic trust in those who know, 'the experts', and those who regulate may be reduced, particularly after events which have illustrated failure to act in such a way as to deserve public trust. This was the case in France after the Chernobyl accident. Although more than 20 years have gone by, and deep reforms have been implemented in the fields of nuclear safety and radiation protection, leading to the creation of two main institutions (ASN, as the independent administrative authority responsible for regulation and control, and IRSN, as the reference public expert body for nuclear safety and radiation risks), the issue of the trustworthiness of these state organisations is still open to public opinion.

However, even if trust cannot be ordered, effective protection of a given population in the event of a radiological emergency presupposes good cooperation between experts, authorities and all those involved.

This is why, in 2006, three years after IRSN was created, a strategic framework contract signed between the institute and the five government ministers responsible for the political oversight of IRSN set forward as a priority need the development of a movement to become known as 'opening to society'. A movement set to bring closer the 'experts' and the 'stakeholders', through the implementation of a long term 'investment in people' strategy.

2. IRSN STRATEGY

The IRSN strategy ‘opening to society’ was designed with a five way approach:

— A sense of leadership had to be established in such a way that it was to be clearly understood, particularly within the institute, that this was not a ‘fashionable’ movement, bound to be replaced sooner or later by some other policy line, but that on the contrary it was actually dealing with fundamental assets which govern the long term future of IRSN;
— A pragmatic method for step by step implementation of change had to be invented to develop actions successfully over a number of years together with key stakeholder organisations;
— This meant in particular organizing cultural change within IRSN itself;
— Outside the institute, experimenting with society at large inevitably means investing in education;
— Finally, as radiation protection is largely a science based activity, the question of how much IRSN R&D in the field of radiation protection deals with issues which are actually of direct concern to society had to be raised.

2.1. Leadership

Beyond the above mentioned STATE/IRSN framework contract, which instituted ‘opening to society’ as one of the four key strategies for the development of IRSN, the following actions were implemented in order to achieve a clear sense of leadership in this policy:

— The quality policy, based on ISO 9001 certification of all IRSN activities, including research, established as a key target ‘maximization of benefits’, in term of prevention of radiological risk, which society at large could draw from all IRSN actions in the implementation of its public missions. The other two quality policy objectives were to ‘satisfy all customers’, and to reach for scientific excellence in all fields of R&D and expertise operated by IRSN. IRSN was successfully certified on this basis in 1997;
— ‘Opening to society’ is not just a slogan. In order to make it happen, a special unit with around 10 staff, including key experts, was set up under the initial leadership of Annie Sugier with the goal to develop actions, both internally and externally, which would drive expected changes in the way IRSN operates regarding stakeholders, and in the way stakeholders perceive IRSN and the amount of trust they are ready to place in the institute, thus improving the efficacy of radiation protection activities;

— Involving the media was another key target. It meant illustrating IRSN actions in such a way as to draw attention to the in-depth changes that were quietly affecting the way IRSN key work processes operated, without altering the satisfaction of immediate beneficiaries of IRSN expertise, i.e. its clients, public authorities, or industry, and IRSN's foreign partners;
— Finally, it was necessary to create a public example of IRSN engagement. For this purpose, a public charter was developed together with other institutes interested in this approach to public expertise missions. The charter can be downloaded fromwww.irsn.fr. It contains six public engagements, three directed at stakeholders (increasing transparency, knowledge sharing, support in acquiring expertise capability) and three at the IRSN itself (providing training on stakeholder involvement issues, providing adequate resources to support the action of opening to society, and requesting feedback on results).

2.2. Step by step pragmatic implementation

Progressively, actions were tested in order to develop the strategy in the most pragmatic and realistic way possible:

— The first development occurred well before this strategy was set up, and can in fact be analysed as the start up event. This is now known as the GRNC pluralistic group, set up by IRSN at the request of public authorities to investigate claims of an abnormally high prevalence of child leukaemia near the La Hague reprocessing plant, back in the 1990s. This successful experience, about which a book has been written[*], demonstrated the power of an approach to health risk expertise developed *with* stakeholders, and the deeply rewarding (but also demanding) nature of this approach for IRSN's experts;
— Later, a framework cooperation contract was established between IRSN and ANCLI, the national association of Local Information Committees (CLI) for each major nuclear facility. This agreement provided training opportunities inter alia, shared operations such as thematic seminars on key issues (nuclear waste management…) and the provision of expertise support by IRSN;
— In 2008, IRSN pledged, in agreement with ASN, to progressively make reports and technical opinions sent to ASN on nuclear risk evaluations,

[*] "Le Groupe *radioécologie Nord-Cotentin.* L'expertise pluraliste en pratique", by Yves MISEREY and Patricia PELLEGRINI, published in 2007 by Documentation Française.

usually established on the basis of the nuclear operator safety files, publicly available on its website;

— Also in 2008, a report was provided to IRSN by the CNDP, the French public institution responsible for operating public debates about major projects affecting significant numbers of stakeholders (such as building a new railway line or a new nuclear power reactor). This report was requested by IRSN for the purpose of extending its strategy of stakeholder involvement. It proposes a roadmap for future developments, which is currently being implemented;

— The year 2008 also saw the first initiative to directly involve stakeholders through the local CLI in the post-incident investigation of uranium pollution consequences in the Tricastin area (southeast of France), following the accidental release of a uranium solution into a small river. This initiative, which is still under way in 2009, has proven instrumental in re-establishing public confidence.

2.3. Cultural change within IRSN itself

The above mentioned charter was developed using a bottom up approach, in consultation with a number of IRSN experts. Training sessions were made available. International experience was also encouraged. For example, the NEA/CRPPH 'science and values in radiation protection' seminar was closely followed by IRSN.

Such actions gradually develop 'good practice', and spontaneous initiatives to respond to stakeholders, and more importantly to think of stakeholder issues before they occur.

The feeling of working together in a society when implementing a new R&D project or when establishing an expert report is gradually pervading the institute in a concrete (as opposed to ideological) fashion.

2.4. Investment in education

IRSN's own readiness for stakeholder dialogue is one thing. This dialogue also requires active and competent stakeholder representation in a field which happens to be particularly complex. One of the main ways to promote the development of such competences while ensuring independence of such a resource, is to work closely with the education community. IRSN has in this way successfully experimented cooperation programmes with some secondary schools, through pilot projects. A more comprehensive project was launched with the community of Monbéliard in eastern France, which led to the creation of an

original art and radiation protection exhibition called “Vous avez dit radioprotection”, which was shown in Buenos Aires at IRPA12 .

IRSN and ASN also jointly operate a more classical technical exhibition, also offering thematic conferences. This exhibition, called “Nuclear Issues and Society” moves from city to city, and is open to the public. Secondary schools also visit the exhibition at each location, in coordination with IRSN.

2.5. Investment in research

Research amounts to nearly 50% of IRSN’s expenditures, so that the institute maintains as much as possible state of the art knowledge in its fields of competence. IRSN research is aimed at improving its capability to comprehend nuclear and radiological risk, and to facilitate risk prevention and remediation whenever necessary, particularly for heavy radiation exposure victims. This research is not discipline oriented, or fundamental research; it could be described as ‘society oriented’, in the sense that it aims to enhance safety and radiation protection.

The question therefore arises of how stakeholder involvement could also play a useful role in the field of IRSN R&D. New developments are now underway to underpin key R&D programmes using stakeholder dialogue. A new committee was established, reporting to the IRSN board, for stakeholder consultation on future R&D programmes in the fields of nuclear safety and radiation protection. At the European level, a new, ambitious approach to low dose risk research is being launched, with the active support of IRSN, in order to provide answers to key societal questions about the effective impact of protracted exposure to low doses of ionising radiation: can we develop valid answers to the long open question of the shape of the dose–response curve for cancer risk and other pathologies, including complex scenarios of protracted internal exposure? What about tissue sensitivity to cancer development? What about individual variability in the prevalence of those risks? Information about this project, called MELODI, which will include stakeholder involvement, can be found on www.hleg.de, in the High Level and Expert Group report to the European Commission.

3. CONCLUSIONS

IRSN is still at the beginning of the road with respect to its opening to society, and a lot more is still to be accomplished. However, several benefits of this strategy can already be identified, including those for IRSN itself:

— The sense of mission felt by IRSN experts and staff in general has been boosted by the improvement of the institute's public image, as reflected in particular in the media: IRSN's goal is not just to provide R&D results and expertise to public authorities, industry and other stakeholders, it is to enhance safety and radiation protection, in France and beyond, through its international connections;
— This, in turn, provides credibility to IRSN's efforts to achieve world class excellence in R&D and expertise, with significant successes in several areas, for example in dosimetry and radiopathology.

However, the most important aspect is the feeling that in any future challenging times facing the institute, proximity with the society provides the best insurance that there are people available and ready to interact with in a positive way, people who would trust and support IRSN's expertise and analyses.

IRPA GUIDING PRINCIPLES FOR RADIATION PROTECTION PROFESSIONALS ON STAKEHOLDER ENGAGEMENT*

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1. INTRODUCTION

During the 11th Congress of the International Radiation Protection Association (IRPA) held in Madrid in May 2004 there were considerable discussions on the benefits of involving all relevant parties in decision making processes related to radiological protection. It was agreed that this involvement, briefly described as 'stakeholder engagement', should play an important and integral part in these processes. A need was identified for guidance to be produced to help radiation protection professionals understand the objectives, requirements and demands of stakeholder engagement, encourage participation and provide a framework for establishing a constructive dialogue with other stakeholders.

As a result of these discussions, a group of professionals from the French, Spanish and UK IRPA associate societies decided to collaborate on organising a series of workshops to exchange information focusing on case studies of how stakeholder involvement had been carried out in different fields of radiation protection. The workshops were held in Salamanca, Spain, November 2005, Montbéliard, France, December 2006 and Oxford, UK, December 2007 and resulted in a draft version of the Guiding Principles. During the course of this development, progress was systematically reported to meetings of the IRPA executive council and at IRPA regional congresses (Paris, France in May 2006, Acapulco, Mexico in September 2006, Beijing, China in October 2006, Cairo, Egypt in April 2007 and Brasov, Romania in September 2007).

A draft version of the Guiding Principles was sent to all associate societies for comments in the spring of 2008. After revision by the executive council the Guiding Principles were presented at the IRPA12 associate societies forum and,

* These guiding principles, presented in the Fourth Background Plenary Session, were endorsed by the Associate Societies Forum and adopted by IRPA's executive council in Buenos Aires; they are now part of IRPA's official documents.

after discussion and with some amendments, endorsed by the forum. The Guiding Principles were finally adopted formally on 18 October 2008 in Buenos Aires by the IRPA executive council.

The Guiding Principles are intended to aid members of IRPA associate societies in promoting the participation of all relevant parties in the process of reaching decisions involving radiological protection which may impact on the well being and quality of life of workers and members of the public, as well as the environment. In promoting this approach, radiological protection professionals will aim to develop trust and credibility throughout the decision making process in order to improve the sustainability of any final decisions.

Principles

Radiological protection professionals should endeavour to:

1. Identify opportunities for engagement and ensure the level of engagement is proportionate to the nature of the radiation protection issues and their context.
2. Initiate the process as early as possible, and develop a sustainable implementation plan.
3. Enable an open, inclusive and transparent stakeholder engagement process.
4. Seek out and involve relevant stakeholders and experts.
5. Ensure that the roles and responsibilities of all participants, and the rules for cooperation, are clearly defined
6. Collectively develop objectives for the stakeholder engagement process based on a shared understanding of issues and boundaries.
7. Develop a culture which values a shared language and understanding, and favours collective learning.
8. Respect and value the expression of different perspectives.
9. Ensure a regular feedback mechanism is in place to inform and improve current and future stakeholder engagement processes.
10. Apply the IRPA Code of Ethics in their actions within these processes to the best of their knowledge.

2. GUIDANCE

2.1. Principle 1

Identify opportunities for engagement and ensure the level of engagement is proportionate to the nature of the radiation protection issues at stake and their context.

The primary purpose of engagement is to contribute to decision making on radiological protection measures so that:

- Measures are more widely understood and respected;
- Measures are optimal and work in practice across a broad range of foreseeable situations;
- Measures are tailored to the local context (social, economic, environmental, etc.);
- Measures will continue to be effective and have credibility for some reasonable period of time.

Engagement will add real value to the decision aiding process and its outcome but its extent and nature need to be proportionate to the radiation protection issues and concerns at stake. This includes being realistic about the cooperation that can be achieved and about the resources and time that might be expended when interacting with more challenging stakeholders. The more complex the radiological protection problem and the more serious the risk, or even the perception of the risk, the greater is the justifiable investment in engagement.

In identifying opportunities for engagement it is important to be aware of changing societal expectations. Changes such as increasing awareness of risks associated with some activities, concerns over environmental deterioration or loss of public confidence in some organizations are all likely to broaden or shift the range of stakeholders that need to be engaged.

2.2. Principle 2

Initiate the process as early as possible and develop a sustainable implementation plan.

Feedback experience has shown that involving stakeholders as early as possible in decision aiding processes generally improves mutual understanding of a situation, and therefore may avoid a deadlock at a later stage. Although it may

increase the duration of a process, involving stakeholders generally facilitates better cooperation between all participants and leads to more acceptable and robust decisions.

Involving stakeholders in the early stages of the decision aiding process will provide an opportunity to develop a sustainable plan in terms of scope, objectives, timetable and milestones, deliverables, knowledge production, financial support etc. In order to improve sustainability of the process, a reasonable approach shared by all participants should be adopted when defining this plan. The process has to be proportionate to the realities of the situation, and take into account stakeholder time and opportunity to participate according to each stakeholder's particular circumstances. Finally, it will be necessary to revise and adapt the plan as the situation evolves.

2.3. Principle 3

Enable an open, inclusive and transparent stakeholder engagement process.

Openness, inclusiveness and transparency, which are interrelated, should constitute the essence of a successful stakeholder engagement process and should always be present. They are the basis for understanding, creating confidence in the process and promoting it. They may be supported by collectively agreed rules and mechanisms for their assessment.

The process should include all the relevant stakeholders, extending representation beyond obvious candidates to all those perceived to have a share in or an impact associated with the risks of the endeavour under consideration. Different expertise and sensibilities will generally enrich the process and provide more validity to the results.

All issues entering into the decision should be considered with openness to identify, select and discuss any associated uncertainties.

During the process, it is important to share information needed to build a collective understanding of the problem, starting in particular with risk communication. The flow of information should be quick, concise, clear to all and honest (in terms of accuracy, uncertainty etc.). By default, information should be accessible to all, recognising that some information truly requires protection. Rather than withholding information on grounds of personal or national security or confidentiality, it is preferable to have it presented in a different way, rather than omit it.

It would be helpful to build, grow, review and maintain a common knowledge pool, identifying a responsible 'gatekeeper' or 'custodian' for the knowledge pool who is trusted and respected by all parties.

2.4. Principle 4

Seek out and involve relevant stakeholders and experts.

A key part of decision aiding is to be very clear about the issue in question, the scope of the problem and the factors that may be relevant. Inherent to this process is the need to identify those who can and should contribute; in short, ensuring that an appropriate diverse range of views are included. A radiological protection professional can help promote this approach, as radiological protection is, by its nature, an interdisciplinary science.

There is a need to reach out to other disciplines and stakeholders, and make them aware of the issues under consideration. Without this first step relevant factors may not come to light, undermining the validity and sustainability of any decision. For example experts in one discipline may not be aware of 'knock on' effects in other areas. Similarly if the net of consultation has been set wide enough to elicit 'no comment' replies, it is useful information to support the bounding of the issue. Bringing together all diverse views may be an iterative process, particularly for large scale decision making, that may involve socioeconomic factors. Thus it should be accepted that the initial set of stakeholders may not be the final set. The process can be a dynamic one with stakeholders joining, or leaving, throughout.

There is a need to respect information and knowledge gained through individuals' experiences as well as that from scientific and technical experts. Some issues, particularly high profile ones, bring with them stakeholders with significantly different points of views. It is important that there is engagement with, rather than avoidance of, these different groups. Inevitably there will be conflicting views and information. How these are evaluated within the decision aiding process is a separate but important element (see principles 3 and 5). However, it is clear that obtaining a full spectrum of views is important.

2.5. Principle 5

Ensure that the roles and responsibilities of all participants, and the rules for cooperation are clearly defined.

A clear definition, at the beginning of the process, of the roles and responsibilities of the different categories of participants (for example, experts, authorities, sponsors, lay persons, decision makers versus decision takers), is important to obtain a shared understanding of what is expected from each and the extent of the influence they may have. In addition it is helpful to clearly set out the rules under which cooperation can be achieved. A clear delineation of the consultation

and decision phases, as well as a clear understanding of where individuals' responsibilities and accountabilities begin and end is essential to clarify conditions of engagement. Potential conflicts of interest should be declared by all parties. It may be helpful for radiological protection professionals to refer to their own Code of Ethics

One of the objectives of stakeholder engagement in a decision aiding process is to promote dialogue and mutual understanding, but not necessarily to reach a consensus on all aspects of the situation. It is thus important to preserve the autonomy of different categories of participants concerning their points of view or their evaluation of the situation. This delineation of roles is a key element to creating conditions for participants to contribute to an improvement of the evaluation of the situation and radiation protection options.

Beyond clarifying roles and responsibilities, sharing rules of cooperation between participants will also favour success of the process.

2.6. Principle 6

Collectively develop objectives for the stakeholder engagement process, based on a shared understanding of issues and boundaries.

The need for a collective approach to developing process objectives is implied by application of the other principles. Principle 2 talks of the development of a sustainable plan, Principle 4 of identifying the responsibility of contributors and of scoping problems and factors, and Principle 5 of the need to cooperate.

Lack of collectivism disenfranchises stakeholders, whereas working alongside each other allows a tight group to emerge which is then capable of explicitly defining process objectives. The group is then in a position to validate these against its shared understanding of issues and boundaries, as well as to collectively agree upon the scope or remit for the work.

Once objectives are identified in principle, discussions can extend to ensuring that they are refined in the light of available resources. The realism brought about by this dialogue invariably leads to more harmonious working by avoiding feelings of frustration with a process that might be perceived as more imposed than negotiated.

2.7. Principle 7

Develop a culture which values a shared language and understanding, and favours collective learning.

In order for all stakeholders to fully appreciate the factors entering into a decision they must be able to understand what is being said. This understanding can be seriously compromised by the use of jargon and technical language as well as acronyms and abbreviations. The radiological protection professional should be motivated to develop a common language, sufficiently precise scientifically to not offend various experts but also sufficiently rooted in common, every day experience to be meaningful to all those involved. Part of this approach is likely to involve formal and informal training of stakeholders leading to the creation of a shared knowledge base incorporating technical concepts essential to a full understanding of the issues.

2.8. Principle 8

Respect and value the expression of different perspectives.

It is important that each participant in the process recognises their own and each others' uniqueness, and, because of this, is aware that other participants have different backgrounds and sensibilities and, therefore, may view issues from different perspectives.

Participants should be aware that some may be experts in their own field, and the integration of their views is an important step in the process, whilst accepting challenges to expert opinion. Evaluation of uncertainties in assessments where expert opinion is divided should be undertaken in an open, accessible and clear manner. Experts should recognise the limits of their mandate.

Respect for one another's views encourages a wide range of thoughts and ideas which can be evaluated as a whole during the engagement process. This acceptance of diverse perspectives, thinking and values has the potential to enrich the process, providing that the process is controlled such that any entrenched views and ideologies, if present, are managed by agreed mechanisms. In a similar way, seemingly radical or novel opinions should not be dismissed out of hand, but evaluated with respect in the same way as other ideas. It is important that each individual sees their own contribution in the record of the meetings.

Participants should be aware that rational thought, respect and acceptance of opinions will tend to be challenged or obscured when discussing issues which are emotive, or issues which have attracted significant media or political interest. Efforts should be made if this happens to restore the desirable climate of mutual respect and cooperation.

2.9. Principle 9

Ensure a regular feedback mechanism is in place to inform and improve current and future stakeholder engagement processes.

When engaging with stakeholders, an opportunity should be provided for both the stakeholders and those responsible for the process to give feedback on the approaches and tools used and on the outcomes. This serves to inform and improve ongoing processes as well as influencing how future processes should be conducted. The following types of criteria might be included in the evaluation: appropriateness of terms and timing of engagement, quality and appropriateness of information provided, comprehensiveness of the issues addressed, inclusivity in terms of the number and diversity of stakeholders involved and the nature of their engagement, and practicability and feasibility of the eventual outcomes.

Stakeholder engagement commonly involves a series of meetings, discussions and other types of face to face encounters. These provide continuous learning opportunities through discussions by the group at the end of each meeting, whereby agreements on improvements in the management of subsequent meetings are made. It should be recognised that implementation of changes may require additional resources and any improvements agreed upon must be realistic and achievable.

When a stakeholder engagement process comes to an end, it is important that those responsible for the process make the results known to all those who participated. If these results do not reflect the recommendations or findings of the stakeholders, those responsible must offer an explanation to the stakeholders for any deviation from what was agreed upon. In this way, the feedback of results and decisions will help to maintain confidence in the process.

Tangible improvements in stakeholder engagement resulting from the establishment of a constructive feedback mechanism will contribute to a more sustainable process, which could serve as a role model for future engagement. Dissemination of lessons learned, achievements and how challenges can be met should be carried out as widely as possible among the radiological protection community.

2.10. Principle 10

Apply the IRPA Code of Ethics in their actions within these processes to the best of their knowledge.

Throughout the stakeholder engagement process, radiological protection professionals should be bound by the IRPA Code of Ethics or an equivalent national code.

SCIENTIFIC AREAS AND TOPICAL SESSIONS

SPECIAL TOPICAL SESSIONS

There were three Special Topical Sessions (STSs): 'Networking in Radiation Safety', 'Legal Implications of Radiation Protection' and 'Stakeholder Engagement in Practice'. Their main contributions and conclusions are discussed below.

STS I: Networking in Radiation Safety

This special Technical Session took the form of a round table and addressed the issue of networking in radiation safety, which is high on the international agenda. A new generation of radiation safety networks has developed over the last 10 years as a result of the evolution of sociopolitical demand and technological advances in communication. Networks are set up at different geographical bases, and vary from worldwide to very local. Sometimes they cover a specific topic (training for example) or a specific domain (cardiology for example), but they are more often multi-topical and multi-sectoral. They always rely on communication and exchanges through direct contact, most often complemented by email, web sites and forums.

The discussion identified that the success of these networks depend on: Personal links and communication;

- Sharing information;
- Enthusiasm;
- Flexibility;
- Collective efficiency;
- Making use of native languages.

They are limited by:

- Limited resources;
- Risk of duplication;
- Confidentiality issues.

International organisations and regulatory bodies need stakeholder networks as a decentralised complement to their actions, but the initiatives have to come from the stakeholders (regions, operators, regulators, medical associations, and in general professionals). Local stakeholders need networks as a tool of mutual help on practical issues and to give them more legitimacy.

It is not reasonable to envisage a single network of networks covering everything; however, it is sensible to avoid duplications. Thus the future is open

not only to the emergence of new networks and new types of networks, but also to the establishment of links between networks and the possibly of creating several networks of networks at all levels — geographical, topical and sectorial.

STS II: Legal Implications of Radiation Protection

This special Technical Session addressed the 'Legal Implications of Radiation Protection' at a lively round table organized in close collaboration with the legal office of NEA/OECD. Presentations and discussions focused on three of the most important challenges facing the international radiation protection community today:

- Liability and compensation for nuclear damage;
- ALARA: A complex approach based on multi-disciplinary perspectives;
- Public participation and public protection.

In short, the conclusion was that there is a need to develop more unified and globally consistent legal obligations for compensating nuclear damages should they occur. There was a clear recognition of the need for both precision and harmonization in the application of radiation protection standards, in particular with regard to ALARA, in order to provide greater legal certainty to regulators, operators, lawyers and the public. And the value of comprehensive stakeholder participation in the decision making processes of regulatory bodies was clearly acknowledged.

Participants considered this session to be very constructive and expressed strong support for continuing to include legal issues in future congresses. It was finally agreed that cooperation between lawyers, scientists and governments on these issues would result in benefits to everyone.

STS III: Stakeholder Engagement in Practice

The Congress emphasized that this session was dedicated to application of the concept 'in practice'. The presentations at IRPA12 showed a growing concern worldwide with the application of stakeholder participation in real world situations, including involvement from France, Italy, Latvia, Norway, Portugal, Spain, UK, EU, Argentina, Brazil, India, and Japan and engagements by international organizations such as OECD–NEA and WHO. The main fields of application were identified as: environmental issues associated with nuclear installations, post-accident situations, occupational exposure, and medical exposure of patients.

Many environmental issues relate to discharges from nuclear installations, and in particular to the diffusion of information on environmental issues associated with discharges. They included:

- Establishing dialogue for sharing information and concerns;
- Developing pluralistic expertise for assessing environmental impact;
- Involvement of local stakeholders with environmental monitoring results;
- Identifying indicators for the assessment of impact on biota.

Other environmental issues obviously related to radioactive waste management. They included:

- Developing multi-attribute approaches for exchanging information;
- Providing feedback of experience regarding difficulties in national debate;
- Involving local stakeholders in addressing the issue of intergenerational transfer of protection;
- Elaborating multi-level consensus;
- Preparing decommissioning activities with stakeholders.

In post-accident management, a number of issues were identified including:

- Addressing agricultural and environmental issues in case of an emergency situation (the INEX exercise);
- Addressing radioecological sensitivity of territories with multi-attribute approaches;
- Involving local stakeholders in the monitoring and elaboration of self-help actions;
- Involving stakeholders in preparedness of post-accident management.

Identified issues regarding occupational exposure included developing networking and ALARA approaches. Expansion and dissemination of public information about radon was considered a central issue, as well as local community engagement for managing radon in dwellings. There were also issues related to medical exposure of patients including involving patients, professionals and organizations in decision making and developing international partnerships to promote public health. Finally, IRPA12 also identified many transcending issues, including:

- Development of a radiation protection culture;
- IRPA society initiatives to promote a radiation protection culture through dialogue with different stakeholders;

- Involving local communities in the promotion of a radiation protection culture through a global approach;
- Addressing the relationship between and communication of science and values with stakeholders.

Participants favoured diffusion and dissemination of approaches and the exchange of experience on stakeholder engagement, based on IRPA's Guiding Principles. They also identified the need for further developments, such as tools and a framework for stakeholder engagement and training. The conclusions of the session can be summarized in three clear points:

- Stakeholder involvement is a real issue. In modern societies, people (both individuals and groups) want to participate in a more direct way in those decisions that affect their environment, their health, in essence … their life;
- Stakeholder engagement in practice is an effective tool to improve the decision making processes, leading to better and more sustainable decisions;
- There are a number of real experiences in this area that have been presented, related to a variety of different fields (environmental issues associated with nuclear installations, post-accident situations, occupational exposure, radon in dwellings, medical exposure of patients, NIR, etc). However, more guidance is welcome on how to conduct the processes and, in this sense, the IRPA Guiding Principles mark a significant step forward.

III.1. RADIATION PROTECTION IN NUCLEAR INSTALLATIONS

This scientific area covered the following topics:

- Radiation Protection in Nuclear Reactors, with 31 papers;
- Other Fuel Cycle Facilities, with 23 papers;
- Decommissioning and Restoration, with 33 papers;
- Radioactive Waste Management, with 53 papers.

TS III.1.1 Radiation protection in nuclear reactors and TS III.1.2 Nuclear fuel cycle facilities

The topics Radiation Safety in Nuclear Reactors and Nuclear Fuel Cycle Facilities included:

- Current radiation protection performance and its supporting robust track record;
- Evolution in radiation protection policies and policy making;
- International policy developments (scientific development, knowledge and key implications of public risk perception and on public policy making and environmental protection);
- Areas for improvement in radiation protection (e.g. programmes, technologies, culture, etc.);
- Perspectives on nuclear energy development;
- Radiation protection system for practices (the success of keeping it simple and flexible);
- Clearance and exemption;
- Global consistency of radiation safety standards;
- Intervention (improved guidance for decision making out of the normal regime);
- Worldwide cooperation for industry radiation protection;
- Staffing, education and training in the nuclear industry;
- Stakeholder involvement (industry practical experiences).

These sessions, which were organized in cooperation with the World Nuclear Association, benefited from excellent participation by senior industry executives from several countries. Their main reflections and conclusions are summarized below.

It was emphasized that a key feature for the immediate future is a global movement toward nuclear renaissance and an extended introduction of nuclear power generation. Thirty-one countries and regions have introduced nuclear power generation and over 20 countries are planning to build new nuclear power plants in the future. Thus, substantial nuclear developments are foreseen around the world over the coming decades. These developments closely relate to the world challenge on energy and the environment. Operators from France, Japan, and the United States of America have all highlighted their practical contributions. IRPA12 also heard from Argentina and Brazil.

The long and solid track record of radiation protection in the nuclear industry is an excellent basis for expansion. Collective doses and individual doses have been steadily reduced over the years. For instance, efforts by the EDF and contractors have reduced collective radiation exposure by a factor of four per reactor in just over 15 y (from 2.44 person Sv in 1991 to 0.63 person Sv in 2007). In support of a global expansion in nuclear energy, all operators are committed to strengthening radiation protection. But there are key areas for improvement and global opportunities, for instance:

- Greater harmonization of the global safety regime;
- Full integration of radiation protection as part of this regime;
- Further development and integration of a safety culture in radiation protection;
- Design and implementation of practical improvements for the most exposed workers and for general working conditions;
- Sharing 'best practices' through industry cooperation;
- Improving public communication about radiation and radiation safety, including the reporting of radiation protection incidents.

Future challenges include:

- Renewal of the radiation protection workforce and skills (attracting new professionals);
- Stability of the competent workforce;
- Education and training programmes;
- Stewardship for emerging nuclear energy countries;
- Extension of radiation protection practices to all relevant professions;
- More balanced and complete coverage of public health policies for the control of exposure.

Additional key points were discussed. There is a great need to develop radiological protection programmes and expert professionals in emerging nuclear fuel cycle countries (mines, conversion, enrichment, etc.). New generation reactors and fuel processes lead to the anticipation of new radiation protection challenges. Radiation protection for new facilities considers improvements already integrated into current models of new nuclear power reactor quality management systems (QMS) and applied to integrated safety. However, there needs to be a concerted effort to instil a safety culture to sustain excellent radiation protection performance. Dose constraints (DCs) were seen as only one of the flexible tools of optimization. However, DCs cannot restrict optimization, because this would be counterproductive. DCs should be flexible and part of an iterative process.

TS III.1.3 Decommissioning and restoration

The topics in the area 'Radiation Protection and Safety in Decommissioning & Restoration' included radiation protection issues on:

- Site decommissioning;
- Restoration and post-decommissioning;
- Stakeholder involvement.

The session underlined that there are many types of facilities worldwide, which are nowadays under decommissioning processes, including nuclear power plants, research reactors, nuclear fuel cycle facilities (from mining to fuel treatment), research facilities and installations (accelerators, medical installations, laboratories), and waste management facilities.

The presentations pointed out that decommissioning is increasingly important beginning with the design phase and continuing throughout the operation of facilities. Early planning and priority processes are both key. End state use, be it vacant field or various types of site reuse (e.g. industrial, commercial, leisure), should be discussed upfront. Characterization is a necessary step for planning and undertaking decommissioning. The radiation protection organization must be involved, e.g. in the transition from operation to decommissioning where contractors need to be fully included. Waste management infrastructures and routes must be identified and implemented. Although a site specific context prevails, a common approach to decommissioning increases credibility, e.g. use of the IAEA safety guides. Thus, a systematic approach to ALARA should be an integral part of decommissioning with monitoring and control. Mechanisms for sharing experiences (e.g. international cooperation) already exist and need to be further developed.

TS III.1.4 Safety in radioactive waste management

The topical session on Radioactive Waste Management included:

- Liquid and gaseous discharge treatment;
- Solid waste management and disposal (very low level radioactive wastes, low and intermediate level radioactive wastes, long lived radioactive wastes, high level radioactive wastes);
- Stakeholder involvement.

The session offered an opportunity to explore solutions for practical problems through describing waste management aspects for diverse sources: a modular reactor (PBMR), the largest research accelerator (CERN), borehole disposal, and a low level (LLW) waste disposal site (UK). Several papers covered radioactive waste management plans (general or national). Two issues involving LLW were flagged as requiring special attention: (1) environmental regulations for radioactive discharges tend to be excessive (huge cost versus tiny dose reduction) and (2) how much of a country's resources should be used? Exclusion, exemption and clearance continue to be controversial issues. Cleanup is important and so is a good sense of proportion and a transparent methodology (cost–dose–risk benefits).

A comprehensive methodology for dealing with uncertainties in the context of clearance levels, consistent with ICRP Publication 104, has been adopted by Japan's regulatory body and could serve as the basis for an internationally agreed upon approach on this difficult issue. Other main points on waste management to be highlighted include the fact that progress has been made in naturally occurring radioactive material (NORM) waste management. Countries without nuclear energy programmes have also progressed with their waste management programmes, and the IAEA has been helpful in this effort. There is a lot of technological knowledge regarding the characterization of wastes as part of waste management programmes, and stakeholder involvement is important in support of decision making as part of the waste management siting process.

Conclusions — Radiation protection and safety in nuclear installations

The main conclusions of presentations made by nuclear industry leaders are that substantial nuclear development is foreseen around the world over the coming decades, which is closely related to the world challenge on energy and environment. Facing that challenge, the long and solid track record of radiation protection in the industry and its outstanding overall performance — with collective and individual doses steadily being reduced over the years — is an excellent basis for expansion.

In support of the global expansion of nuclear energy, all operators are committed to strengthening key radiation protection areas for improvement with greater harmonization of the global safety regime. This includes full integration of radiation protection as part of this regime and further development and integration of safety culture in radiation protection. Also important are the design and implementation of practical improvements for jobs with the highest exposure and for general working conditions, sharing of 'best practices' through industry cooperation, and improvements in public communication about radiation and radiation safety, including the reporting of incidents.

Future challenges for the nuclear industry include renewing and sustaining a competent radiation protection workforce. This requires education and training programmes. Additional important needs include stewardship for emerging nuclear energy countries, extension of radiation protection practices to all relevant professions, and a more balanced and complete coverage of public health policies for the control of exposure.

Radiation protection challenges must be anticipated in emerging nuclear fuel cycle countries (mines, conversion, enrichment, etc.) and in radiation protection improvements integrated in currently offered new designs for nuclear power reactors. They incorporate quality management systems (QMS), applied to

integrated safety and safety culture, and which are the best drivers for sustaining excellent radiation protection performance.

The area of decommissioning and restoration is a young and growing field; from the beginning planning is the key to success. It is an interdisciplinary activity requiring a multi-industrial team and good expertise.

Stakeholders and the regulatory authority must be involved in preparing preliminary papers in order to solve problems during the process. The transition of an operational facility to one that is decommissioning is not an easy process because of the change of 'culture' that it implies. However, clear objectives promote the best possibilities for reuse of sites, whether or not it is for future nuclear activities. IAEA publications have been developed to cover all radiological safety aspects and have a systematic approach to ALARA. In the future, sharing experiences and international cooperation will be increasingly important.

Both operators and regulators have shared experiences and proposals on radioactive waste management. Many papers were presented from countries that currently find themselves in the 'strengthening the national infrastructure and regulatory framework' phase and from countries with consolidated regulatory bodies and a regulatory framework. Operators covering the spectrum of installations from nuclear medicine to nuclear power shared their experiences in the management of radioactive wastes, including disposal, future projects, and benefits and advances.

In general, all participants agreed with the conclusion that radioactive waste characterization is fundamental to optimizing options for 'disposal' and 'long term storage'. In relation to this topic, mathematical models were presented for radioactive waste characterization and its application to specific installations and processes. Research work was presented with new ideas and technologies applicable to radioactive waste characterization as well as to enhancement of the radioactive inventory of certain residue types.

Finally, it is important note that everyone emphasized the need for operators and regulators to work together towards harmonization in 'national policy and corresponding strategies', taking into account the very long times that radioactive waste management implies and therefore the involvement of future generations. Despite all efforts by the international community, a number of issues remain over which international consensus has yet to be achieved. The IAEA set of waste safety requirements and safety guides, presented at IRPA12, offer a good opportunity for solving the waste management conundrum of public acceptance.

III.2. NON-IONIZING RADIATION APPLICATIONS

This scientific area covered the following topics:

- Power Frequency Electric and Magnetic Fields (EMF), with 21 papers;
- Mobile Telecommunications, with 9 papers;
- Optical Radiation, with 7 papers;
- Ultrasound Emerging EMF Technologies, with 8 papers.

This scientific area was developed in full throughout IRPA12, including the aspects of:

- The epistemology of radiation and biological effects;
- The paradigm of radiation protection from the regulatory view;
- The practice of radiation protection on the use of plans and methodologies to control radiation fields.

There was a significant contribution of presentations and a good number of attendees at the technical sessions and refresher courses. Also, just before IRPA12, the Argentine Society of Radiation Protection organized a local NIR workshop, in Spanish, that was attended by about 200 people.

TS III.2.1. Power frequency electric and magnetic fields (EMF)

Topics on Power Frequency EMF included:

- Public exposure from power frequency fields (power lines, substations and domestic wiring);
- Occupational exposure from power frequency and other extremely low frequency (ELF) fields (welding, smelting, induction);
- Measurements and computational modelling of ELF field interaction with the human body;
- Measures to control and, where relevant, reduce ELF exposures;
- Risk analysis, communication and management;
- Development of technical standards and exposure guidelines on ELF.

TS III.2.2. Mobile telecommunications, TS III.2.3 Optical radiation and ultrasound and TS III.2.4 Emerging EMF technologies

Topics discussed in the area of Mobile Communications included:

- Public and occupational exposure from mobile phones, base stations, emergency radio systems, etc;
- Measurements and computational modelling of radiofrequency (RF) field interaction with the human body;
- Measures to control and, where relevant, reduce RF exposures;
- Risk analysis, communication and management;
- Development of technical standards and exposure guidelines for radio-frequencies.

Topics discussed in the area of Optical Radiation and Ultrasound included:

- Public and occupational exposure from ultraviolet radiation devices (e.g., sun beds);
- Public and occupational exposure from lasers and other high intensity lights and lighting systems;
- Use of lasers and other high intensity light sources in medicine and for cosmetic purposes;
- Public and occupational exposure from infrared emitting devices, infrared heaters and saunas;
- Measurements and computational modelling of optical radiation interaction with the human body;
- Occupational, diagnostic and therapeutic exposures to ultrasound;
- Measurements and computational modelling of interaction of ultrasound with people;
- Measures to control and, where relevant, reduce optical radiation exposures;
- Risk analysis, communication and management;
- Development of technical standards and exposure guidelines on optical radiation;
- Development of technical standards and exposure guidelines on ultrasound.

Topics discussed in the area of Emerging EMF Technologies included:

- Occupational, patient and volunteer exposure from magnetic resonance imaging (MRI);

- Public and occupational exposure to wireless communication devices (body worn transmitters, WiFi, baby alarms, etc.);
- Public and occupational exposure to electronic personal identification, electronic articles surveillance, radiofrequency identification and metal detection devices;
- Measurements and computational modelling of fields from emerging, technology devices and their interaction with people;
- Measures to control and, where relevant, reduce EMF exposures (risk analysis, communication and management of emerging EMF technologies and health);
- Development of technical standards and exposure guidelines on emerging EMF technologies).

Conclusions —Radiation safety in non-ionizing radiation (NIR) applications

With regard to radiation safety in non-ionizing radiation (NIR) applications, the aim was to include all aspects of the epistemology of radiation and biological effects, the paradigm of radiation protection from the regulatory view, and the practice of radiation protection in the use of plans and methodologies to control radiation fields.

A new stochastic model of carcinogenesis induced by ionizing radiation considers breaking the barrier mechanisms of a cell as a key feature of carcinogenesis. The barrier mechanisms (e.g., antioxidant defense, repair, apoptosis) represent the complex of cell responses to primary cell damage caused by exogenous and endogenous factors. This approach can be applied for ionizing or non-ionizing radiation and indicates the advantages of collaborating on studies of the effects of ionizing and non-ionizing radiation. A similar conclusion can be made with a presentation on modelling living cells as signals.

Regarding the paradigm of radiation protection for NIR, use of the precautionary principle in health protection policies regarding electromagnetic fields was emphasized.

Also the practice of radiation protection against NIR was covered, particularly the use of plans and methodologies to control radiation fields. The application of computational dosimetry studies to assess electromagnetic field exposure in the vicinity of EMF sources was emphasized.

III.3. MEDICINE

This scientific area addressed radiation protection in:

- Diagnostic Radiology, with 109 papers;
- Interventional Radiology, with 40 papers;
- Nuclear Medicine, with 68 papers;
- Radiotherapy, with 49 papers.

In these sessions, the following topics were considered:

- Design, shielding and monitoring of new medical radiation facilities, including PET/CT facilities, nuclear medicine departments, therapeutic nuclear medicine facilities (wards, theatres and waiting areas), and radiotherapy facilities (including particle therapy);
- Assessment and monitoring of patient dose in diagnostic and interventional radiology, computed tomography, diagnostic and therapeutic nuclear medicine, PET/CT, radiotherapy (including particle therapy), and paediatrics;
- Addressing the issue of optimization, including consideration of dose and diagnostic outcome, quality assurance, health screening (e.g. CT "health-checks", mammography screening, colon screening, osteoporosis screening), benefit versus risk to research subjects, dealing with pregnancy and potential pregnancy issues;
- Lessons learned from incidents, near misses and accidents;
- Education and training.

TS III.3.1. Radiation protection in diagnostic radiology

The topics on Radiation Protection in Diagnostic Radiology included:

- Quality control;
- Dose measurement (methods, analysis, devices);
- Phantoms and software development;
- Monte Carlo simulation on Voxel phantoms;
- Dose audits at local, national, and regional levels;
- Mean doses;
- Paediatric doses in computed tomography;
- Proposals for establishment of diagnostic reference levels (DRLs) for adults and children;
- Methods for analysis and audit of image quality;

- Technology changes, such as faster film screen (FS) combination;
- Computed radiography (CR);
- Direct digital radiography (DDR)/flat panel;
- Fluoroscopy.

The importance of patient dose evaluation was highlighted. DRLs are effective optimization tools and should be developed for both adults and children. Paediatric doses in CT procedures are, in some cases, similar to adult doses, which may also be higher than necessary. Therefore, there is a need to develop optimized scan protocols, especially for paediatric patients. Although in general mean patient doses are found to be within international reference doses, it is important to evaluate image quality (IQ) and to establish optimized dose–IQ relationships. Dose and image quality audits are important, but it was found that audits at the local, national, and regional levels all show large variations.

A sequence designed to survey practices, train staff, and then resurvey practices can be used as a model to assist optimization.

Finally, it was reported that computer modelling had advanced to the point that voxel phantoms should be used for dose evaluation whenever possible. The use of dose length product (DLP) instead of tube loading is more appropriate for CT shielding calculations.

TS III.3.2. Radiation protection in interventional radiology

The topics on Radiation Protection in Interventional Radiology included:

- Staff dosimetry;
- Staff education and re-education;
- Patient dosimetry;
- Technical issues related to radiation protection.

Regarding staff dosimetry, it was pointed out that there is no regulation or harmonization of the use of double dosimetry. Single dose badges can considerably underestimate doses and the location of dosimeters has to be linked to the algorithm in use. The use of active dosimeters, which display the dose to the wearer as a procedure progresses, is useful in the reduction of staff doses. There is increasing concern over extremity doses, especially fingers, knees and gonads. The lack of use of lead aprons by some personnel, as well as the quality of aprons and their regular checking are also matters of concern.

Cataracts have been reported among professionals who work in interventional radiology for several years without appropriate radiation protection.

In relation to patient dosimetry, concerns were voiced about skin injuries caused by combined factors, such as prolonged localized fluoroscopy, multiple radiographic exposure and repeated procedures.

The main points covered regarding technical issues in interventional radiology were: quality assurance, grid controlled fluoroscopy, test instruments, new equipment, phantoms and contrast media.

The session concluded that the practice of interventional radiology is safe and highly beneficial to patients, but that the levels of radiation are among the highest used in medical imaging and therefore a number of recommendations were made, as follows:

- ICRP recommendations should be followed in order to properly protect patients undergoing interventional radiology as well as involved staff;
- Medical doctors employing fluoroscopically guided procedures need to be trained and certified in this practice;
- X ray systems used for interventional radiology should be submitted to a strict acceptance and commissioning process;
- Industry should continue to implement dose saving options for interventional systems and improve standardization and archiving of dosimetry data;
- Industry should develop software to estimate skin dose distribution and organ doses; such data would facilitate the selection of patients in need of clinical follow-up;
- Occupational dosimetry should be improved, including dose assessment for different parts of the body;
- Because of the uncertainty concerning cataract risk, there should be particular emphasis on the optimization of protection in situations of exposure to the eyes;
- Patient dose surveys and the use of diagnostic reference levels (DRLs) should be extended, including to paediatric patients.

TS III.3.3. Radiation protection in nuclear medicine

The topics on Radiation Protection in Nuclear Medicine included:

- Dosimetric aspects (exposure rates and individual doses; internal doses to patients and staff, doses to caregivers);
- Radiation protection in paediatrics and patients undergoing renal dialysis;
- Optimization (administered activities and image quality; uncertainty assessment in dose calculation);
- Quality assurance (software validation and quality control measurements);

- Computer modelling (voxel phantoms and beta radiation fields);
- Increasing importance of short lived radionuclides (F-18, other PET nuclides).

The session reached few but important conclusions, as described below:

- Regarding occupational exposure in nuclear medicine; the results from comparison of various treatment regimes and equipment may be the input for setting facility specific dose constraints;
- Further research in needed for real time measurements on equivalent doses to extremities;
- Occupational exposure doses in PET facilities are a high cause of concern. One of the reasons for this is the lack of clear guidelines for the design of PET/CT installations (site planning and shielding);
- There is an increasing emphasis on quality assurance (dose calculations and imaging equipment);
- The use of voxel phantoms, which reproduce patient characteristics with high fidelity, is of great importance for calculating patient doses and should be recommended for use whenever possible;
- The use of diagnostic reference levels (DRLs) for patient doses of nuclear medicine examinations should be promoted;
- Criteria for classification and design of nuclear medicine departments need to be reviewed, particularly regarding quantitative specifications for ventilation.

TS III.3.4. Radiation protection in radiotherapy

The topics for Radiation Protection in Radiotherapy included:

- Optimization in treatment planning (intensity modulated radiation therapy-IMRT, respiratory gated radiotherapy and image guided radiation therapy-IGRT);
- Beam calibration and characterization;
- Radiation shielding for protection of workers and the public;
- Patient dose assessment;
- Treatment delivery and verification;
- New radiotherapy technologies;
- Prevention of accidental exposures (lessons learned and proactive safety assessment).

Several cases of Monte Carlo simulations of dose distributions and special new phantoms for quality control of complex treatments were presented. Other specific methods for validation of dose verification or estimation of patient doses and distribution in common treatment situations were also presented. Different methods for determination of absorbed dose to water in reference conditions and in irregular fields were analysed in several papers. These methods included the use of different ionization chambers, development of algorithms, postal audits, and measurements with bipolar phototransistors.

Occupational exposure was estimated in several types of facilities including proton and particle radiotherapy facilities. Estimation of neutron doses and instruments for neutron measurements were also presented.

The evaluation of compliance with appropriate manufacturing standards for ^{60}Co units and the specifications of an Electrostatic–Quadrupole accelerator facility for Boron Neutron Capture Therapy were presented. An innovative dosimeter was proposed for on-line in vivo quality assurance consisting of an optically stimulated luminiscence detector.

A recent radiotherapy accident was reported, including a description of the succession of dysfunctions and human errors which lead to the event. The approach for identification of affected patients and their medical management was presented. A proactive safety assessment tool to avoid accidental exposure during treatment with accelerators was described. This approach allows systematic identification and anticipation of all potential causes and provides help in establishing priorities in terms of QA. It also recommended there be adequate staff and sufficient training for all members of the team.

It was concluded that new, highly conformational RT presents challenges such as dose escalation, reduced margins, steep gradients or high accuracy in terms of dose calculation, delivery and verification. Tools such as inverse planning or Monte Carlo simulations are needed for those techniques to validate their safety. In addition, since radiation therapy is a practice in which radiation doses are intentionally applied to human beings is the highest, the application of the requirements for QA must be more stringent to assure radiation safety.

Conclusions — Radiation protection and safety in medicine

Significant attention was addressed to emerging challenges concerning radiation protection of patients undergoing radiological medical procedures.

Strategies for improving justification of medical procedures in **diagnostic radiology** should be developed.

The use of guidelines as decision aiding tools for referring physicians should be promoted.

Diagnostic reference levels (DRLs) need to be established as effective optimization tools. It is important to evaluate image quality (IQ) and establish an optimized dose/IQ relationship. Voxel phantoms should be used for dose evaluation when available.

Methods for dose reduction involving equipment and software design, operational parameters and shielding calculations should be considered. This is particularly relevant for children: optimized protocols should be applied to paediatric patients.

Radiation protection in **interventional radiology** was particularly emphasised. Main issues were identified in occupational radiation protection and patient dosimetry. There is a need for harmonization of criteria for monitoring staff dose including use of double dosimeters, real time dosimeters and dose assessments for different parts of the body. The use of lead aprons should be promoted and particular emphasis should be placed on optimization of protection in situations involving exposure of the eyes.

The control of patient doses in interventional radiology requires that DRLs be established when possible and regular dose assessments be made. In addition, paediatric levels are still needed because adult dose settings should not be used for paediatric patients. Use criteria for advance identification of high skin doses should be developed.

The primary conclusion for protection in interventional radiology is that interventional radiology is safe and highly beneficial to patients, though levels of radiation are among the highest used in medical imaging. Therefore, specific ICRP recommendations should be closely followed.

Regarding **nuclear medicine**, intercomparison of various treatment regimes and equipment appears to be useful for setting facility specific dose constraints for protection of workers. There is a need for guidance in the design of facilities, particularly in PET/CT installations (ventilation, site planning and shielding).

Quality assurance in nuclear medicine was given particular emphasis. The use of voxel phantoms is recommended for calculating patient doses. DRLs (administered activity) should be established and applied as a tool for optimization.

The practice of **radiotherapy** has caused the most accidental harm. Several conclusions were expressed. Highly conformational radiotherapy produces new challenges such as dose escalation, reduced margins, steep dose gradients and highly accurate dose calculation, as well as dose delivery and verification. Tools such as inverse planning or Monte Carlo simulations are needed for those techniques to validate their safety.

Since radiation therapy is the practice of intentionally applying high radiation doses to human beings, the application of requirements for quality assurance must be more demanding to assure radiation safety.

New and rapidly evolving technologies require qualified personnel. Health professionals need to be properly and regularly trained in radiation protection.

Implementation of appropriate regulations involving the participation of health authorities and medical professionals is essential. Because regulation in this area may involve more than one body, with each having different responsibilities, harmonization and better coordination among multiple stakeholders is necessary.

III.4. NORM IN INDUSTRY

This scientific area covered the following topics:

- NORM in Uranium Mining and Processing, with 12 papers;
- NORM in Other Minerals Mining and Processing, with 28 papers;
- NORM in Oil and Gas Industries, with 11 papers;
- NORM and Radon Issues in Building, with 31 papers.

TS III.4.1. NORM in uranium mining and processing

Topics on NORM in Uranium Mining and Processing included:

- Techniques for the monitoring and surveillance of uranium and its decay products at uranium mines;
- The environmental impact of uranium mining and milling;
- Radiological impact on workers;
- Development of regulatory policy for uranium mining.

A resurgence in the uranium industry has led to the rapid expansion of mining and processing operations. This has emphasized the shortage of trained and experienced radiation protection professionals, a situation that cannot be corrected quickly. There is a need to develop uranium mining regulations and radiation protection procedures in many countries experiencing an expansion in uranium mining. A culture of productive interaction between regulatory bodies and operators should be developed. All parties need to cooperate to achieve high levels of excellence in the management of radiation health, safety, waste and the environment. A strong safety culture should be based on internationally shared

principles and ‘best practices standards’ and is particularly needed in emerging uranium producing countries.

Social acceptance will depend on proper management and public education to allay unnecessary concerns regarding uranium mining and processing. International organizations (IAEA, WNA, ICRP, IRPA, OECD/NEA) have an important role to play in disseminating guidance and information.

TS III.4.2. NORM in other minerals mining and processing

Topics on NORM in Other Minerals Mining and Processing included a wide variety of industries generating waste streams or product streams that are enhanced in NORM. Examples of industries covered in this session were:

- Thorium in rare earth minerals;
- Phosphate industries;
- The coal industry;
- Scale on water pipes;
- Areas of elevated background radiation.

Several papers gave comprehensive reviews of NORM industries in various countries to document the scale and scope of the problem. NORM industries usually produce large volumes of low activity material which has the potential to cause chronic low level exposure, often over many years. Legacy sites and decommissioning were discussed in several papers. Papers were also presented on methods of modelling the distribution of NORM, evaluation of exposures from NORM, and estimation of dose.

Following the publication of ICRP 103 it became clear that the system of radiation protection includes management of NORM either as planned exposure or existing exposure situations. In applying these recommendations, regulatory instruments and management tools need to be flexible to handle a wide variety of situations and to apply the optimization principle.

In conclusion, the limits of regulations need to be defined with emphasis on a graded approach and flexibility accounting for site specific and local conditions. Interchange of staff between industry operators and regulators, as well as improved training, is encouraged. Stakeholder engagement is necessary using evidence based on realistic scenarios. Analyses have identified a number of situations in which unacceptable doses exist, but the conclusion was that they can be easily handled. Finally, the assessment of occupational exposure at two NORM industries concluded that higher doses observed corresponded to areas with very low occupancy factors.

TS III.4.3. NORM in oil and gas industries

Topics on NORM in Oil and Gas Industries included:

- Oil and gas industry with its sub-product of radioactive scales;
- National surveys;
- Occupational health.

Several papers reported on countrywide surveys with the aim of creating a picture of the scope and scale of the problem. There were reviews of NORM in various Brazilian facilities and of oil fields in equatorial regions of South America. Papers reported on the development of safety manuals, management strategies and regulatory frameworks in other countries including Saudi Arabia and Belgium.

Surveys in oil fields show large volumes of scales and sludge with activity concentrations containing dose rates ranging from background levels to 150 mSv/h. The dose rate from one pump was reported to be 400 mSv/h. Very high levels of radon gas, 400kBq/m^3, were reported in a propane gas stream. Several papers concentrated on the disposal of NORM wastes and the decommissioning of equipment and installations which have been contaminated by NORM.

Occupational health and safety problems associated with maintenance of pipes and equipment were presented. Measurements of radium isotopes were used to assess Th/U ratios in geological formations and the use of liquid scintillation techniques was reported for the measurement of ^{222}Rn, ^{228}Ra, ^{226}Ra, ^{210}Pb and ^{210}Po.

In conclusion, the management strategy for NORM in these industries will be defined by the special precautions needed for cleaning or maintenance of contaminated components, and the need for disposal sites for NORM wastes. Decommissioning of these installations will require the disposal of a large amount of scales and sludge contaminated with NORM. In this regard, the upcoming challenges include occupational and disposal aspects. Protective measures are needed to reduce occupational doses. There is also a need to define a permanent solution for waste storage and reduction of waste volumes.

TS III.4.4. NORM and radon issues in buildings

Topics on NORM and Radon Issues in Buildings included:

- Surveys and dose measurements for a variety of situations;
- Measurement and modelling of the magnitude of exposure from NORM;

- Management of risks, in particular those from wastes and residues;
- Regulation of NORM.

The session was characterized by the presentation of a large number of papers on a wide variety of topics which in itself is a reflection of the ubiquitous nature of NORM. Building materials, and their radon emanation, are one of the most wide spread sources of exposure to NORM. The issues discussed related to measurement techniques, including measurement of radon and thoron in building materials, homes and workplaces. Measurement programmes to characterize radionuclide concentrations and methods for dose assessment were presented. The dilemma of reducing individual or collective doses was discussed, as well as regulatory regimes to control exposure. Problems related to disposal of TENORM wastes were noted. There is recognition of the need to improve knowledge in this important area of public exposure. Similar issues were raised at the Topical Session TS III.5.3 on 'Radon and the Public'.

Conclusions — Radiation protection and safety for NORM in industry

The use of NORMs in industry is another practice having a large radiological impact in which common issues are:

- Regulatory policy;
- Environmental impact of uranium mining and milling;
- Radiological impact on workers and on the public.

The conclusion for NORMs in uranium mining and processing can be summarized as follows: since the uranium industry is undergoing a renaissance, updated radiation protection procedures and regulations are urgently needed; there is a shortage of trained and experienced radiation protection professionals who cannot be produced overnight; public education on the issue is required; interaction between regulators and operators must be stressed; all parties need to work to achieve high levels of excellence in the management of radiation health, safety, waste and the environment; a strong safety culture should be based on internationally shared principles, particularly necessary for emerging uranium producing countries; "best practices standards" need to be introduced; social acceptance requires proper management; and international organizations (e.g., IAEA, WNA, ICRP, IRPA) have to play an important role.

On NORMs in the mining and processing of other minerals, the following issues were addressed: thorium in rare earths, including phosphates; coal; country reviews; models for evaluation; elevated background; and scale on water pipes. It is clear that a wide variety of industries produce NORMs, usually large volumes

of low activity material, and several countries have undertaken comprehensive reviews for measurement of NORMs and dose estimation. It was re-emphasized that the system of radiation protection include NORMs, but regulatory instruments and management tools need to be flexible in handling a wide variety of situations. Legacy sites and decommissioning are open issues in the immediate future.

On NORMs in oil and gas industries, the main issues were: countrywide surveys; pipe scales and sludge; measurement techniques; decommissioning; and the radon problem. Surveys in oil fields have shown large amounts of scales and sludge (with dose rates of up to 150 μSv/h [400 μSv/h in a pump], and 400 kBq/m^3 of radon gas in propane stream). The main issues are: maintenance of pipes and equipment, disposal of NORM wastes and decommissioning of installations. Measurement challenges include liquid scintillation for ^{222}Rn, ^{228,} ^{226}Ra, ^{210}Pb and ^{210} Po, identification of radium isotopes, assessing Th/U in geological formations, and dating scales and contaminated soils.

On radiation safety for NORMs and radon issues in buildings, IRPA12 featured a large number of papers on a wide variety of issues such as: measurements and modelling; regulation; surveys and dose measurements; management of risks and waste; radon buildup in workplaces; radioactivity in building materials; radioactivity and tobacco (smoked in building ambiances); measurements and modelling in a variety of situations; and regulation and management of materials.

The conclusions for the area of NORMs in industry can be summarized as follows:

- The first challenge is to know what's out there: there is wide variety of NORM industries (uranium, rare earths, coal, oil, gas, phosphates, mineral processing and others) and NORMs can concentrate in products, by-products and residues; there exists exposures to large populations with small doses, exposures to small populations with larger doses and occupational exposures and the challenge is how to measure those; there are difficult measurement situations, such as measurement of low activity or activity concentration, long decay chains and disequilibrium, hard to measure radium, radon, thoron, ^{210}Pb, ^{210}Po; modelling of exposure pathways should be done with a lot of assumptions and averages adopted to widely varying situations; assessing doses of individuals with large uncertainties, particularly for internal exposure;
- The second challenge is what to do about it: there is no single solution to the management of NORMs, a wide variety of regulatory instruments are required; a graded approach including exclusion, exemption, clearance, notification, registration and licensing is needed; recognition of managed as

planned or existing exposure situations; dose constraints and reference levels are not clear; numbers of people exposed and magnitude of exposures should be optimised within dose bands; flexibility is required!

III.5. OTHER APPLICATIONS AND PRACTICES

This scientific area covered the following topics:

- Radiation Protection in Transport of Radioactive Materials, with 17 papers;
- Radiation Protection in Industrial, Research Applications and Security Screening, with 31 papers;
- Radon and the Public, with 49 papers;
- Radiation Protection in Flights and Space, with 8 papers.

TS III.5.1. Radiation protection in transport of radioactive materials

Topics on Radiation Protection in Transport of Radioactive Materials (which featured a special round table) included:

- Regulations;
- Package design;
- Package approval;
- Package operation and maintenance;
- Radiation protection programme;
- Emergency response, management system and quality assurance;
- Security;
- Education and training.

Round table presenters and participants reflected four common themes that are prevalent today in the transport of radioactive materials: safety records, increase in shipments, denial and delay of shipments and security.

The transport safety record over the last 50 years has been excellent, with no serious injuries or deaths caused by the radioactive nature of the material being transported. Some of the credit for this can be attributed to the strength of the IAEA's transport regulations, the resulting robust package designs that must be used for high activity materials, and the consistent adoption of these regulations by countries and international organizations.

With the expected expansion of nuclear power and increases in the availability of nuclear medicine applications, shipments of radioactive material will continue to increase in the foreseeable future. These shipments highlight the

benefits that nuclear technology brings to society and the necessity for transportation which supports the realization of these benefits.

Whenever a shipment is refused or delayed, particularly for short lived medical isotopes, there is a corresponding denial of benefit to the intended recipient, sometimes with corresponding adverse economic and security impacts. The IAEA, countries, and regional organizations have begun addressing this problem through dialog and identification of actions to improve the situation. The Montevideo Group in South America has initiated a reporting system to identify specific instances and help focus corrective actions where they are most beneficial. Additional efforts are planned for the international community to identify how it can interact with carriers to improve their knowledge about these shipments and their willingness to accept them.

Security during transport is a key issue in today's political environment. However, making security requirements for radioactive material more stringent that those carriers normally meet for other dangerous goods could increase denial of shipments. A balance is needed for security requirements to ensure that materials are adequately protected during transport without being disruptive or burdensome to carriers' operations.

TS III.5.2. Radiation protection in industrial and research applications and security screening

Topics on Radiation Protection in Industrial, Research Applications and Security Screening included:

- Isotope production and processing;
- Accelerators for industrial use (new materials, sterilization, etc.);
- Isotopic tracers in industrial processes;
- Industrial instrumentation with radioactive sources (automatic process controllers, gauging);
- Non-destructive testing (radiography using X rays, gamma rays and neutrons);
- Moisture and density measurement in soils and other applications;
- Research applications of radiation;
- Application of radiation for security and customs purposes (human screening, baggage screening, cargo screening, new technologies).

There are multiple beneficial uses of ionizing radiation in industry, security and other applications. A method was presented for producing ^{99}Mo and ^{131}I from low enriched uranium targets, with a description of radiation safety benefits achieved with this new method, including the reduction of nuclear wastes and

total iodine emissions. Increasing investment in the use of non-intrusive means of detection at customs and, as a consequence, the need for qualified persons in the radiation safety area, was highlighted. The role of radiation safety officer within customs was discussed, as well as the difficulties of this position, and the benefits that collaboration of an officer can bring to the implementation of a safety culture. The regulatory and radiation safety issues taken into consideration in the licensing of a mobile security screening device that employs backscatter X ray technology were also presented.

The issue of security screening was an important topic in this session, due to growing security concerns worldwide leading to the introduction of new screening technologies using ionizing radiation. The U.S. Interagency Steering Committee on Radiation Standards (ISCORS) Guidance for Security Screening of Humans utilizing ionizing radiation was presented. The EU requirements with regard to medical and non-medical imaging — focusing on radiation safety issues regarding the use of radiation for security screening — were summarized. Proposed security screening requirements for revision of the BSS were also presented. During the general discussion period, questions about the justification of security screening were raised. The main conclusions are related to the benefits of using ionizing radiation in industrial and research applications as well as in security screening. However, as this use also entails risk, the principles of justification of the practice, optimization and application of dose limits should be taken into account.

TS III.5.3. Radon and the public

Topics on Radon and the Public included:

- Radon risk assessment;
- Radon risk communication;
- Exposure guidelines and action levels;
- Radon concentration measurements and techniques;
- Mitigation techniques and cost effectiveness of mitigation actions.

In many aspects, the conclusions can be shared with those of the topical session TS III.4.4 NORM and Radon Issues in Buildings.

The major challenges continue to be measurement and dose assessment in air, soil and water; dwellings, caves and spas; measurement techniques, and; regulatory aspects, including reference levels. The World Health Organization (WHO) sponsored International Radon Project is a good start for reducing the population disease burden due to radon in homes; it involves the participation of more than 30 countries and includes awareness, risk communication,

measurement, cost and effectiveness of control, and remediation. Factors affecting cost effectiveness and health benefits in relation to remediation programmes include suitability of short term measurements, seasonal correction factors, remediation of several story dwellings, and the impact of smoking cessation programmes.

TS III.5.4. Radiation protection in flights and space

Topics on Radiation Protection in Flights and Space included:

- The assessment of air crew external dose;
- Computational methods;
- Development in instrumentation and methods (calibration procedures, irradiation facilities, uncertainties, harmonisation of procedures for determining individual dose intercomparisons, and standardization);
- Regulatory framework and legal contexts regarding air crew radiation protection;
- Space dosimetry methods;
- Radiological support during space missions.

This session started with a presentation on policy in this controversial subject area. A consolidated explanation of cosmic ray radiation safety was presented, including characteristics of galactic cosmic rays.

A special lecture was presented by the International Federation of Air Line Pilots Associations (IFALPA). In 2003, an IFALPA policy of cosmic radiation was decided and the structure of a guideline was presented. Doses in jet air flights had been followed by several countries and were discussed. Discussions also centred on dosimetric aspects, biological effect, and dose calculation, with the conclusion that fostering information exchange between pilots and other cabin crews should be encouraged. There was lively discussion on the issues of dosimetry in space flight. Measurements with TLDs for space stations in low orbit space flight were presented and discussed. Medical and biological aspects were examined. Mars missions and their requirements for a special consideration of shielding were also discussed, among other issues.

Conclusions — Radiation protection and safety in other applications and practices

Generally accepted evidence demonstrates that risk from radioactive materials during transport is small. Nevertheless, denial of shipments by carriers

is on the rise and is a main issue of concern. This situation, which may be caused in part by fear, as well as economics, must be addressed.

Radiation protection in industrial and research applications and security screening covers a wide range of applications. The main issues identified were sampling and measurements, operational protection, detection systems, improving imaging and licensing issues. The application of X ray screening for security reasons that may involve exposure of persons is increasing and in many cases seems to be proceeding ahead of regulations that would provide for adequate protection.

Many conclusions regarding radiation safety for NORMs and radon issues in buildings are applicable to the controversial issue of public protection from radon exposure, an area in which major challenges continue to exist, including: measurement and dose assessment in air, soil and water, dwellings caves and spas; measurement techniques, and; regulatory aspects, including reference levels. Factors affecting cost effectiveness and health benefits of remediation programmes are: suitability short term measurements, seasonal correction factors, remediation in several story dwellings, and the impact of smoking cessation programmes. It is clear that much progress has been achieved in measuring and assessment, but it is necessary to strengthen actions for awareness and risk communication. The application of remedial actions seems to be very low at this time.

The main issues regarding radiation protection measures for crews in commercial airlines were: studies of biological indicators for assessing risk in air crews; programmes for calculating dose for given flight routes for personal use; and involvement of airline pilots.

The main issues in the area of radiation safety in space continue to be: dosimetry and specific radiation science, feasibility of operational radiation protection for astronauts, particularly protection during prolonged space mission, and; on board measurement in space stations. A specific radiation protection framework may need to be implemented to provide adequate protection of workers from unnecessary and excessive exposure to environmental radiation in space and to deal with its subsequent biological consequences.

WORKING LUNCHES

RADIOLOGICAL SECURITY: AN EVOLVING STRATEGIC PRIORITY

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Abstract

The theme of this conference is how we need to formulate shared, consensual strategies on radiological safety/security issues to maximize the protection of people and the environment. Within the context of this conference, the comparative significance of safety and security is to be discussed. What do these two concepts mean? How do they differ? The problem that appears within the area of safety and security is the inability of decision makers to define aims, objectives and policy, given that members have different interests, ideologies and visions of the world. The objective of strategy is to understand existing conflicts and define courses of action to solve them. A good strategy requires a clear and shared purpose, committed leadership executed by credible organizations and a fundamental communication mechanism that features a logical and consented common language which allows us to understand and make ourselves understood.

1. INTRODUCTION

The motto for the IRPA12 Congress is "Strengthening of Radiation Protection Worldwide". To achieve this objective, the Congress will focus on three core areas:

— The epistemology of radiation;
— The paradigm of radiation protection;
— The practice of radiation protection.

Analysis of the sessions that make up this conference allows us to visualize and understand the diversity of scientific disciplines, the variety of application fields and the high interaction with other areas of human activity. This analysis defines the complexity of the problems we are faced with.

The theme of this conference will focus on how we need to formulate shared strategies on radiological security issues, to maximize the protection of people and their environment.

2. RADIATION SECURITY STRATEGIES

Consistent with the spirit of this conference, we would like to ask ourselves what strategies would strengthen the security level that this complex system requires.

The definition of a strategy is only possible in the real world by consensus, agreement or power. We have only one possible path, consensus.

The first step is to define the scenario; this involves establishing the actors, their culture and their world view, the latter regarding those who operate facilities, society as a whole, and those who see this world of radiation as a field with which disruptive actions can be undertaken with destructive objectives.

To delineate a radiation security strategy, characterization of the actors is required, which is difficult because they are many, which makes it necessary to harmonize the different cultures that generate particular visions and interests.

Each of the actors has, in some way or another, a culture that was built on three basic elements: scientific knowledge, personal experience and ideological values.

The individual or group culture has a particular vision of the world, a set of interests to defend and it even its own language.

The passive agents — so-called stakeholders and society as a whole — act in an unpredictable, unexpected and even inconsistent way and are likely to join the scene bringing even more complexity to what is already a complex system. Scientific truths become obvious fallacies as a consequence of the powerful action of communication media.

The virtual world is confused with the real world.

A good strategy requires a clear and shared purpose, committed leadership executed by credible organizations and a fundamental communication mechanism that allows us to understand and make ourselves understood.

To harmonize the different visions that each actor has of the world, it is necessary to have a shared language with which to build a strategy, which uses policy to determine goals, and planning as a means of achieving aims.

Thus while the aim of this conference refers to the processes of building a radiation protection strategy, the means to achieve this implies the need to have a common language.

2.1. The actors

In a quick reading of the IRPA12 agenda, we can appreciate the cultural diversity of participants. With just the mention of topics discussed and the origin of exhibitors, the direction of debate is obvious, covering:

- Nuclear installations and the fuel cycle in the energy industry and the proliferation of nuclear weapons;
- The analysis and understanding of effects of ionizing radiation and its interaction with medical and industrial applications;
- The study of non-ionizing radiation and its strong relation to the world of communications and electric and magnetic transmissions;
- The understanding of natural radiation in relation to the oil industry and other related mining industries.

With the participants in these fields of knowledge, we must build strategies without excluding from this interaction the security elements facing countries, and fundamentally stakeholders, as well as society as a whole, which ultimately will condemn us or give us their blessing.

2.2. Characteristics of the strategy

Strategy differs from planning because it does not deal with facts or concrete things and therefore is a step away from traditional science. This is the area in which the differing vision each participant has of the world is resolved. Knowledge is abstract, its language is nominal, and its rationality is not deductive but volitional and based on the cultures of the actors. It is the world of values and ideologies and thus of permanent disagreements on different issues.

In the theoretical and practical construction of the strategy, not everyone always refers to the same world, but it is important to at least make the effort to try.

Ecological fundamentalists face the nuclear problem with a theoretical vision of a world so removed from reality that they make us feel many times like Galileo Galilei must have felt trying to tell the world that the earth revolves around the sun.

We all know that an accident in one place is an accident everywhere.

2.3. Strategy and language

One problem we see is that in general, languages are highly infected by politics and ideologies.

All social literature currently considers social phenomena to be linguistic constructions. That is, when we talk about social phenomena we are not talking about what things are, but of the representations we build of things by means of language icons or symbols used. The only way to solve this problem is to construct a logical and common language.

In this brief expose we will begin to build a shared language so that from there we can start thinking about a joint strategy to face the future.

Charles Morris was very clear with regards to symbols. When we see a word, we think of its meaning and feel something about it that is not the same for all, and that causes a difference between what we see, think and feel regarding a symbol. Their counterparts are the syntactic, semantic and pragmatic dimensions.

Radiation security is a symbol which many see, think and feel differently about. What we have to build is a social software, that is, a shared language that defines how we understand ourselves. The language is knowledge and knowledge is the language.

We have no knowledge that is not expressed in language, but if it is not expressed in language we do not have knowledge. Thus, knowledge is not innate but acquired, This comes from Aristotle, the idea of form and matter, which is the software and the hardware. Aristotle distinguished thing and matter, which is experienced through the senses, while forms are experienced by the mind. The mind has a symbolic construction; matter is the hardware, which has a chemical structure.

First we learn language and then we learn about the world. Knowledge emerges from language, which emerges from knowledge. The communication media has led us to lose the meaning of the words we use. Abbe de Condillac reminds us, “we think only through words ... and ... the art of reasoning should not be any more than the use of a well articulated language” “The limits of my language mean the limits of my world,” defines Wittgenstein.

2.4. Communication

How can we define a strategy with different languages? We could make a list of needed terms to share, but we understand that for us two words occupy centre stage: safety and security.

An interesting step would be to clarify ideas associated with the word ‘security’ and its counterpart ‘radiological terrorism’, and ‘safety’, implicitly associated with ‘quality’ of facilities and aptitude of operators.

This would allow us to build a shared common language so that from there we could start building a comprehensive global strategy to strengthen radiation protection and thus contribute, within our limitations, to the central objective of this conference: strengthening radiation protection worldwide.

3. RADIATION SECURITY

In recent years many have begun to worry about the possibility of various actors starting to employ the spectre of irradiation to induce panic in the population. This possibility has given rise, in recent years, to the emergence of what appears to be a new discipline in the field of radiation protection, so-called radiation security.

There is much confusion on this subject, with many pseudo experts rendering false or at least confusing opinions.

This has resulted in the requirement of large expenditures in order to be able to impede a possible attack on facilities and, nonetheless, it does not appear that we are really ready to face this risk. I humbly express that the Argentina Regulatory Authority (ARN) has repeatedly warned of this issue.

Inspired by these thoughts, it can be argued that proper application of the concept of radiation security is in the definition of a common strategy against today's so-called 'radioactive terrorism'.

In fact, I am convinced that there is high public apprehension regarding radioactive terrorism, which in some cases is used to prevent nuclear projects associated with electrical generation, fuelled by the lack of appropriate technical vocabulary. This confusion is augmented by incorrect language, and is employed by society, politicians and more than a few scientists. The magic word used and misused in the world today is 'security' or, more accurately, 'security against terrorism'.

My question is, what do security and terrorism mean? It seems like the world of computers advances on our thoughts. We oppose the black to the white and the zero to the one as if we were thinking in terms of Boolean algebra which, although a language of tremendous importance in the development of computer science, is limited in interpretation of the world. Boolean algebra has two acceptable values, true and false. We seem immersed in a world in which security is the alter ego of terrorism and seem to believe that one exists because of the other.

Thus a binary logic has being created in our language, with basic concepts the logical syntax of which deliberately ignores what has been called the semantic and pragmatic dimensions, confusing the essence of terrorism — which is a military tool of ancient origin — with the actor called terrorist, which is implementing a strategy for an unknown purpose. Security exists independently of the existence of terrorism and terrorists.

3.1. Safety versus security

Safety and security are two different terms in English, but in many other languages, including Spanish, a single term is used to embrace these two concepts. Not surprisingly, therefore, many of our radiation protection experts wonder what the difference between safety and security is. If they knew that their English speaking colleagues are not necessarily wiser and consulted their dictionaries, they would understand that one of the definitions of security is safety and that one of the definitions of safety is security.

Within the context of this conference, the comparative significance of safety and security should be made more precise. What does 'radiation safety' and 'radiation security' mean? How do they differ? **'**Radiation safety' should relate to actions which lower the probability of radioactive accidents likely to cause injury, death or potential damage, while 'radiation security' should refer to the prevention of any unauthorized possession and/or any prohibited action involving radioactive substances and the radiation they generate. It remains thus that while the goal of safety is preventing and restricting damage attributable to radiation, the goal of security is to prevent or inhibit unauthorized possession and unlawful use of radiation sources. Therefore, radiation security is achieved if we ensure two objectives: that control systems prevent the installation of any device capable of emitting radiation from being abandoned, and that control systems prevent devices or facilities from being purchased or removed inappropriately.

This defines radiation security as a strategy dependant on the strategic goal of radiation safety. Therefore we can say that a radioactive source can be safe in terms of security, but not safety. The reverse is not true, while security is a necessary condition but not sufficient for safety.

With this definition of security, many accidents have occurred due to security violations and they have been the cause of serious radiation accidents. None were caused by 'terrorist' actions, but rather by what may be considered non-malicious violations.

Over time, many people have unconsciously been the cause of security violations causing unforeseeable accidents. Radioactive sources that should have been kept under control were abandoned with no malicious intent. Adequate control over certain radioactive materials was abandoned unintentionally. Many radiation sources have been found orphaned of any control with no malicious purpose. The detailed causes and consequences of some of these accidents have been reported widely in scientific literature.

In summary we can state that, if the statement is correct:

(a) The strategic objectives of radiation security are intertwined and dependent on radiation safety;

(b) Any facility authorized under the terms of radiation safety implies the need for its authorization in terms of radiation security;
(c) When observing the definition we give to the words radiation safety and radiation security, we infer that the strategies to strengthen radiation protection are different;
(d) These statements present additional difficulties generated by new born security specialists, especially after 11 September 2001. They claim that radiation security should have a higher priority than radiation safety. Since they are not professionals in the field of radiation, the interpretation of events is different, especially because of the language they use and the knowledge they possess. If we accept this definition, a new strategic vision appears.

3.2. Argentina and radiation security

In 1998, the IAEA organized the first international conference on radioactive sources in Dijon, France. The agenda of the conference was launched by ARN. Following specific recommendations, the IAEA General Conference for the first time decided to implement an international action plan to strengthen the overall security of radioactive sources.

At the request of the Government of Argentina in December 2000, another international conference was convened by the IAEA in the city of Buenos Aires. The Buenos Aires conference recommended actions to update and strengthen the Dijon action plan. The Board of Governors of the IAEA and the IAEA General Conference adopted the Action Plan in September 2001.

3.3. Non-consented strategies

The lack of consensus on strategies leads us to create policy duality and unspecific goals. For example, some perceived failures are:

(1) The code of conduct is a dual policy. It is applied conscientiously and wilfully but not because of a binding consensual commitment. Today we do not know whether radiation sources and facilities are more secure.

The world has failed to agree on a binding agreement for the handling of sources and facilities. We need an international convention in this area, an international treaty on radiation safety that includes radiation security. Today we have in place a code of conduct on safety and security of radioactive sources. We do not have a convention which imposes the control of radiation sources on countries.

The code of conduct is a moral code without mandatory application, it was a decision driven by the G8 Summit held in Evian, France on June 2003. Today hundreds of countries endorse the code of conduct.

(2) What is the level of accident for which emergency systems should be prepared?

We need to have clear dimensions of the size and scope of a potential accident on which to plan our emergency system.

(3) Is our medical infrastructure ready and capable of responding to a major nuclear accident that could result in thousands of victims of radiation effects?

In the area of medical infrastructure, for example, despite enormous progress in the science of radiopathology, we are not able to cope at the international level with a major accident. The world has accumulated vast experience in dealing with overexposed people, but resources would be insufficient in the case of a major episode. If an event of great magnitude occurs, the existing capacity for a fast, exact and retrospective determination of absorbed dose would be overwhelmed, and end in a sub-optimal outcome for victims of such an event and the potential mismanagement of medical resources designated for their care.

4. CONCLUSIONS

The objective of strategy is to understand conflict and define courses of action to solve them. Following Herbert Simon, the conflict that appears in security is the inability of groups to make decisions, that is, to define aims, objectives and policy, given that its members have different interests, ideologies and interpretations of the world.

The scene of conflict with radiation security is different from that which occurs in radiation safety, although both have characteristics of uncertainty in their interpretation.

In both cases we must discern the thoughts and feelings of the actors as independent entities, or as coalitions or groups, lined up behind ideologies that are neither shared nor understood.

Experience tells us that strategy has to do with the willingness and motivation of men. Simon (2) presents a work, for which he was awarded the Nobel Prize in 1978, in which he says that man makes decisions in uncertain

environments using mental mechanisms different from those used in rational times.

While both radiation safety and radiation security involve the same players, the former takes ecological fundamentalists and stakeholders into account as main players. With these players in mind, radiation safety must include strategy and thus a common language, without which all scientific efforts to solve safety problems fall into the depths of unresolved conflicts.

Radiation safety should be incorporated into the discussion of strategy with actors who come from traditional security elements/institutions, and the culture and world vision of the actors, who may potentially use radiation as a destructive mechanism, must be understood.

Thus the big difference existing between safety and security is the quality and incidence of groups involved in defining strategies.

Although there may be differences in building and defining strategies, we are inevitably compelled to have a common language. If the meaning of words is different, conflicts deepen and cannot be resolved. If we cannot build and internalize dialectical thinking and use a common language to interpret it, conflict is exacerbated by the impossibility of setting up a dialogue.

A common language mitigates conflict as a result of the interaction of one database with another.

So how would I alter conflict? Communicate with different databases to acquire information needed to develop a mutual vision of the world or a worldview with a greater capacity to understand different worlds.

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RADIATION PROTECTION ASPECTS OF CANDU-6 RETUBING PROJECTS

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Abstract

Retubing existing CANDU® reactors to extend their operating lifetime for another 25 ~ 30 years is economically appealing. Currently, AECL is contracted to retube Bruce A, Point Lepreau, Wolsong 1 and Gentilly-2 nuclear generating stations. Other potential retube/refurbishment projects in the future include Embalse and Pickering B Nuclear Generating Stations. Retubing a CANDU reactor involves replacement of the fuel channel components of the reactor, the feeders and some miscellaneous reactor components in the reactor face area. In contrast to construction of a new nuclear reactor, retubing nuclear reactors that have been in operation for many years involves removal of reactor components and installation of new reactor components in a radiation containing environment. Depending on individual contracts, retubing projects may also include design and construction of a waste storage facility and transfer of retubing wastes to the facility. Careful planning of the radiation protection (RP) programme is crucial to ensure protection of workers and the environment during retubing operations. The programme emphasizes as low as reasonably achievable (ALARA) initiatives from an engineering design perspective, and applies ALARA principles throughout the retubing project. This paper describes key RP activities currently underway in AECL's retubing projects, including ALARA for retubing tooling and system designs, RP for work package preparation, RP for training, RP during retubing operations, and RP for waste transfer and management. ALARA considerations in tool and system design have significantly enhanced the tool and process design from an RP perspective. RP training and mock-up training for retubing workers will further ensure minimization of radiation exposure to personnel during retubing operations. Finally station specific RP procedures are strictly followed during retubing operations and for waste management.

1. INTRODUCTION

Most retubing wastes (e.g. fuel channel components and the feeders) are radioactive because of neutron activation of materials within the core during normal operation and accumulation of radioactive deposits in the heat transport system. Working with these radioactive wastes challenges radiation protection

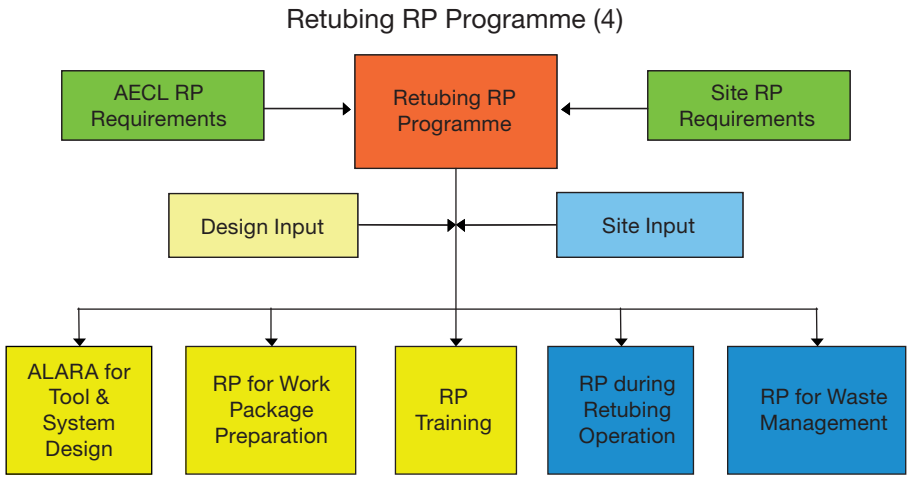

FIG. 1. AECL Radiation protection programme for a retubing project.

and health physics procedures and would be hazardous to the safety and health of workers unless appropriate prevention principles are applied. In applying these principles and practices, proper management, training and properly assigned responsibilities minimize these radiation hazards.

Retubing operations go beyond the normal scope of plant operation or outage activities. A specific radiation protection (RP) programme has been developed and implemented as an integral part of AECL's retubing projects. This RP programme, driven by ALARA principles, takes into account social and economic factors and defines RP activities throughout the retubing project to ensure that workers, the public and the environment are well protected.

This RP programme also ensures retubing projects comply with radiation safety requirements governed by the IAEA, by applicable regulatory agencies and by AECL radiation protection policies and contractual obligations. Figure 1 schematically shows the role of AECL's RP programme in a retubing project.

The RP programme identifies the following major RP activities:

- ALARA for tools and system design;
- RP for construction work packages preparation;
- RP training;
- RP and ALARA practice during retubing operations;
- RP for waste management.

2. BASIC RADIATION PROTECTION PRINCIPLES

The following three RP principles are based on International Commission on Radiological Protection (ICRP) [1] recommendations:

- **Principle of justification**
  'The benefits of working in a radiation environment must outweigh the drawbacks.'

  Retubing a CANDU reactor provides great economic savings over construction of a new reactor.

- **Principle of optimization**
  (ALARA principle: as low as reasonably achievable)

  'Radiation exposure caused by the use of radiation must be kept as low as reasonably achievable.'

  The driving force and primary principle of RP is ALARA. AECL prepares an ALARA plan that provides optimization guidelines for a project.

- **Principle of limitation**
  'Exposure of radiation workers and individuals of the public must not exceed dose limits.'

  As an important RP activity, a series of dose rate targets are defined throughout the project to limit radiation exposure to workers.

CANDU-6 retubing projects have established a safety culture which recognizes the importance of RP at each stage of the project, from design to training to operations.

The RP programme is established on the basis of:

- Knowledge of practices that result in occupational exposure;
- Feedback of operating experience (OPEX);
- Familiarity with factors influencing individual and collective doses;
- ALARA principles.

3. RADIATION PROTECTION IN RETUBING TOOL AND SYSTEM DESIGN

Retubing is divided into a number of smaller jobs called retube series. In each retube series, AECL designers define the work location, prerequisites, tools required, and estimate work duration and personnel requirements. Radiation protection in this design process provides the radiation dose environment for all retube series so that designers can optimize operations to limit personnel exposure to potential radiation hazards.

The RP programme requires that all retube tool designs follow the ALARA tool design guide. The designs are reviewed and approved by a radiation physicist to ensure that RP has been adequately addressed.

AECL's volume reduction system (VRS) (see Figure 2) is an example of the implementation of RP in retube tool design and demonstrates application of ALARA principles by considering:

- Shielding requirements;
- Personnel movement;
- Equipment interfaces;
- Human factors.

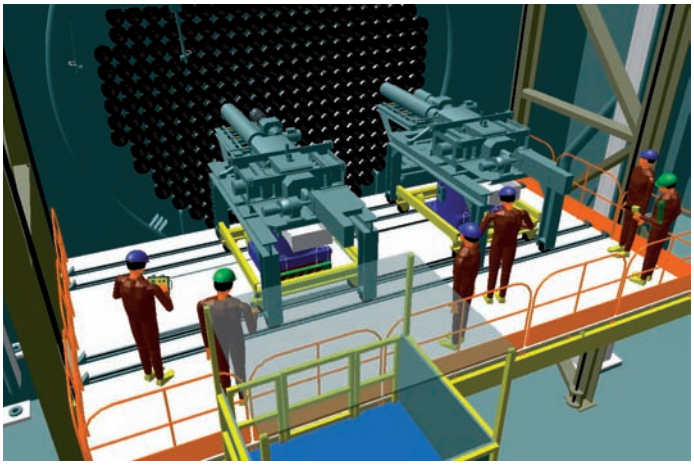

FIG. 2. ALARA Principles considered during the design of volume reduction system.

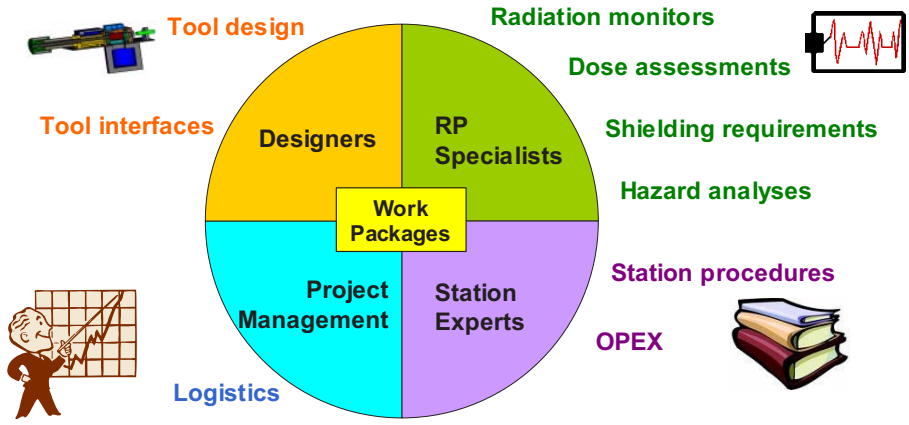

FIG. 3. RP contribution to overall work packages.

4. RP IN WORKING PACKAGE PREPARATION

RP supports working package preparation by providing detailed radiation dose rate estimates for each retubing operation. Radiation environment analysis and a preliminary ALARA dose assessment for each retube series are important inputs (along with hazard analysis and human factor analysis) (see Figure 3) which allow the project organizers to:

- Plan the work using appropriate operation as well as site RP procedures;
- Conduct necessary ALARA assessments for certain high dose expenditure work in accordance with the ALARA site programme;
- Develop project specific RP procedures;
- Establish radiation monitoring requirements for each activity;
- Determine RP assistant requirements.

5. RP TRAINING

RP training is a very important step to reduce radiation exposure to personnel. It ensures that work is performed according to procedures so that RP measures are properly followed. The AECL retube training plan requires that:

- All retube workers receive basic RP training in accordance with site RP requirements;

- In addition, personnel directly involved in retubing project field work must be thoroughly trained using mock-ups.

6. RP AND ALARA PRACTICE DURING RETUBING OPERATIONS

An AECL retubing project team works closely with site RP staff to make sure that the project is well integrated into the site RP programme.

This means that retubing operations must abide by site RP and ALARA procedures. In addition to following site procedures, AECL may also develop retube specific procedures, and define dose rate limits for retube transient operations.

Some transient operations (replacement of fuel channel components) will create a high radiation hazard. In order to limit personnel radiation exposure and for design purposes, a retubing project sets a transient dose rate limit of 10 mSv/h in areas where workers could be present. This transient dose rate allows for the development of a viable shield design needed to attenuate radiation fields from radioactive components withdrawn from fuel channels.

7. RP IN WASTE TRANSFER AND WASTE STORAGE

Large amounts of radioactive waste produced during retubing are packaged and transferred out of the reactor building for storage at the waste storage facility.

AECL prepares a waste management plan specifically for a retubing project. The plan:

- Categorizes retubing waste into intermediate and low level waste;
- Identifies site RP procedures to be followed for treatment, transport and storage of retubing waste.

8. SUMMARY

This paper describes the RP aspects of AECL's retubing projects, which are designed specifically for retubing CANDU reactors. The RP programme complies with IAEA radiation safety requirements and well as those of applicable regulatory agencies and AECL's radiation protection policies and contractual obligations. The RP programme follows three RP principles; job justification, optimization (ALARA) and limitation of dose rate, and focuses on radiation

protection initiatives from an engineering design point of view. The RP programme ensures a structured RP approach for AECL's retubing projects.

REFERENCE

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CLOSING SESSION

CLOSING REMARKS

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The 12th International Congress of the International Radiation Protection Association (IRPA12) has reconfirmed the strong scientific basis on which radiation protection is founded. On one hand, physical sciences characterizing radiation exposure have reached a high level of sophistication. On the other hand, the biological sciences that estimate radiation health effects have undergone a great deal of development in the last years, reaching a level of insight that was unimaginable just a few years ago. Significant advances in the description and quantification of ionizing radiation, as well as a better understanding of radiation exposure effects were presented at the Congress. They have transformed our related knowledge from implicit simplicity to intricate complexity. The final outcome of an exposure situation will probably continue to be simply described by a bare nominal radiation risk coefficient, expressed as probability per unit of effective dose incurred, but the biological mechanisms leading to health effects from radiation have proven to be extremely sophisticated and complex.

IRPA12 has shown that radiobiology has come far from the simple target model for radiation effects, which was the preferred paradigm for expressing radiation induced harm as recently as the IRPA10 Congress just a decade ago. Plenty of papers were submitted to the Congress describing complex mechanisms for the interaction of radiation with living matter. Bystander effects, genomic instability, adaptive responses, abscopal effects, and clastogenic plasma factors are among the great variety of recently discovered cell and tissue response mechanisms that were discussed at the Congress. A new understanding of radiation effects is emerging which describes how complex the outcome of radiation interaction with cell structure is. IRPA12 has shown how much is known about this complicated phenomenon, perhaps much more than is known about the interaction of other pollutants with cells; but the Congress has also shown how much is still unknown. The knowledge limitation seems to be even greater when proceeding from radiation induced cell damage to its final expression in health effects.

Notwithstanding a number of epistemological limitations in biological and epidemiological knowledge of radiation health effects, IRPA12 not only reconfirmed that high radiation doses causing enough cell death will induce serious tissue damage (so-called ‘deterministic effects’), but also provided new

evidence on dose thresholds above which these effects are to be expected — which should facilitate the prevention of their occurrence. The Congress also provided an enormous amount of information on new procedures for diagnosing and treating deterministic effects, including a large number of new biological and pathological techniques.

The epistemological situation is different for protracted health effects that may occur following low radiation doses (so-called 'stochastic effects'), notably radiation induced leukæmias, cancers, and hereditable effects. On one hand, IRPA12 established that there is not enough knowledge to attribute with certainty health effects in relation to very low level radiation exposure. On the other hand, however, the Congress reconfirmed that a radiation risk may and should be assigned to low dose exposures: namely, that latent deleterious health effects may plausibly occur following low dose exposure situations — even if the effects themselves can not be proven. The latter provides the basic rationale for requiring radiation protection procedures even at low radiation doses, regardless of how small, in order to limit radiation risk.

It seems that clarification of the issue of attributing stochastic health effects to low dose exposure situations will require further scientific efforts. This may ultimately be the major challenge for the forthcoming IRPA13 Congress. Biology and epidemiology may not be necessary helpful in solving this important conundrum. Epidemiology has intrinsic epistemological limitations, as estimates on effect incidence become unfeasible at low doses or in cohorts containing low numbers of people, and the Congress showed scepticism over the possibility that (by the time IRPA13 is scheduled to take place) a biological marker could be discovered that would be able to diagnose radiation related stochastic effects with absolute certainty. In any case, the Congress was informed that the UN General Assembly has requested UNSCEAR to report as soon as feasible on the important issue of attributability of health effects to low doses of radiation.

Therefore, it was clear at IRPA12 that estimation of radiation risk for radiation protection purposes will continue to be based on extrapolations from radioepidemiological studies of cohorts that incurred relatively high radiation doses. The Congress was informed of many studies currently underway. Between now and IRPA 13, the outcome of a number of these studies will be available, but others will have to wait for IRPA14. Meanwhile, risk estimates will continue to rely on current evidence. The latest epidemiological estimates have been just recently compiled by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and communicated by UNSCEAR to the United Nations General Assembly; they were reported by the UNSCEAR Secretariat to IRPA12. These can be summarized as a lifetime cancer mortality risk, after a dose of 1000 mSv, of ~0.6–1.0% for leukæmia and ~4.3–7.2% for all solid cancers combined. This is lower for men than for women, with the proviso that lifetime

cancer risk estimates for those exposed as children might be a factor of 2 to 3 times higher than estimates for a population exposed at all ages. The International Commission on Radiological Protection (ICRP) informed participants during the Congress that, taking into account these estimates, it recommends the use of detriment adjusted nominal risk coefficients for radiation protection purposes of 5.5% Sv^{-1} for cancer and leukæmias and 0.2% Sv^{-1} for heritable effects, making a total risk coefficient for a whole population of 5.7% Sv^{-1}, and that corresponding values for an adult population (typically workers) were 4.1% Sv^{-1}; 0.1% Sv^{-1} and 4.2% Sv^{-1}, respectively. It was noted at the Congress that while these coefficients are numerals (expressed in % Sv^{-1}, which when multiplied by the effective dose incurred may quantify the plausibility of harm), they are nominal (namely, the stated numeral does not necessarily correspond to its real value: it relates to hypothetical (not real) people who inter alia are averaged over age and sex) and they are also detriment adjusted (namely, the numeral is a multidimensional figure expressing plausible expectation of harm, which includes inter alia the weighted plausibility of fatal and non-fatal harm, and life lost should harm actually occur). It seems, therefore, that the detriment adjusted nominal risk coefficient of around 5% per Sievert used in current radiation protection standards will continue to provide the basis for radiation protection at low doses until IRPAl3 and beyond.

The ICRP is an exceptional non-governmental organization which would perhaps be impossible to create today; however, in 1928 when it was founded, the world of science was perhaps less polluted by politics and vested interests and thus the ICRP could be established and was able to serve the radiation protection community over so many decades. IRPA12 was proud to host the ICRP jubilee with its 80 years of rich radiation protection history. Universal agreement on a protection model against a given pollutant is uncommon and the radiation protection community should feel very proud to have been able to reach a global consensus on an applicable radiation protection paradigm thanks to the work of ICRP. New ICRP recommendations were presented and discussed at the Congress. For IRPA12 it was clear that radiation protection will continue to rest on the paradigm used worldwide and recommended by ICRP, which continues to be based on three fundamental and internationally accepted principles: justification of any action that changes exposure levels, optimization of radiation protection, and individual dose restrictions aimed at preventing determinist effects and limiting radiation induced risks.

IRPA was informed that new ICRP recommendations provide the basis for an ongoing revision of the major document governing international radiation protection regulation, the international basic standards for protection against ionizing radiation and the safety of radiation sources; the so-called BSS. The Congress learned about the international revision process of this fundamental

document. In fact, IRPA12 provided one of the first opportunities to discuss the evolving international radiation safety regime that is being built under the aegis of the International Atomic Energy Agency (IAEA) and the Inter-Agency Committee on Radiation Safety which includes all relevant organizations within the UN family.

An important outcome of this regime, which was reported at IRPA12, is governmental approval of a unified and single set of fundamental safety principles. These have been compiled into a 'safety fundamentals' document, which aims to be the leading text for a hierarchical pyramid of international radiation safety standards. Safety Fundamentals establishes 10 principles which are common to the all relevant safety fields, including: nuclear safety, radiation safety, water safety, and transport safety (an artificial disciplinary separation representing a confused history more than a real separation of safety issues). It means that all safety requirements within the system, including the BSS, will derive logically in a top down approach from the agreed upon 10 principles. Globally, this means that radiation protection should be considered as a primary part of an integrated safety regime. Radiation protection should not and will not lose its specificity, but it must be taken into account that its paradigm, rules, partners, etc., are part of a larger concept; the concept of an integrated safety regime covering all types of exposure situations, actual and potential, and all types of installations from modest X ray diagnostic equipment to sophisticated nuclear installations.

This vision may have a greater number of consequences than were discussed at IRPA12. The Inter-Agency Committee on Radiation Safety might consider enlarging its scope to become a fully integrated international safety regime. Revision of the BSS must take into account the concept of an integrated safety regime. Such an integrated safety regime should recognize the role of the BSS as the ultimate topical basis for protecting people from radiation exposure (whether they be actual or potential exposure situations). Thus, IRPA12 recommended as a possible topic for the forthcoming IRPA13 the fundamental issue of finding a path towards an international safety regime.

Finally, IRPA12 clearly demonstrated that radiation protection is well ingrained in all practitioners using ionizing radiation. From required infra-structure to specificities of protection of the public, workers and patients, including special arrangements for emergencies and response, all are high on the agenda for these practitioners. However, or notwithstanding this commitment to radiation protection, there is a dominant issue that was especially heavily discussed at an IRPA12 round table: the very important topic of education and training in radiation protection. Without educated and trained people, all theories around an international safety regime would be just that: theory, conjecture and speculation, but not real fact. The IAEA's initiative to create regional training

centres providing postgraduate education and training in radiation safety was very much welcomed. Argentina has been the first country selected to officially provide such a service; its post-graduate course on radiation protection has a history of more than a quarter of a century and many radioprotection officials in Latin America have been trained using this programme.

It was also clear at IRPA12 that there are huge differences among practitioners in the state of implementation. The nuclear industry seems to be well ahead of other industries in that respect; it is well regulated and follows the international paradigm. It has reached superb levels of radiation protection excellence. Medicine is once again looking at the problems that gave birth to radiation protection in the first place, discovering new ones, and attacking them expeditiously. Other industries, such as NORM industries, have just realized they have a problem and are struggling to solve it. In any case, radiation protection practitioners in nuclear, medical, and other activities making use of radiation are fully engaged with the progress reached by the fast growing global radiation safety regime.

In summary, IRPAl2 was met its self-imposed challenge of ‘strengthening radiation protection worldwide’. This was the result of many factors: the massive concurrence of experts from all over the world; the quality of their interactions, discussions and reflections; and; the robustness and global reach of their findings and conclusions. Conversely, IRPA itself was perhaps not up to the expectations of this wide audience. North Atlantic radiation protection societies undertook a short-sighted approach at the IRPA General Assembly, which took place parallel to IRPA12. With a solitary exception they voted against radiation protection professionals from outside the North Atlantic region to take over leadership of IRPA. Hopefully, the next four years — which will undoubtedly bring new progress to the profession — will also provide space for introspective reflection on this unacceptable discrimination. The forthcoming IRPA13 in Glasgow, Scotland, could thus become the event leading a better attitude, so that IRPA can genuinely search not only to ‘strengthen radiation protection worldwide’, as it did at IRPA12 Congress, but also to ‘strengthen worldwide leadership for the radiation protection profession’.

I have great expectations of and look forward to IRPA13 in Scotland!

FUTURE TRENDS AND RECOMMENDATIONS FOR STRENGTHENING RADIATION PROTECTION WORLDWIDE

OUTLOOK FOR THE EPISTEMOLOGICAL BASIS OF RADIATION PROTECTION

The epistemological basis of the sciences of radiation exposure and its effects, which provides the foundation for radiation protection, was generally corroborated and found to be sound, reliable and sensible.

IRPA12 has demonstrated the strong scientific basis on which radiation protection is founded. The physical sciences used to characterize radiation exposure are very sophisticated and continue to evolve. The biological sciences used to estimate radiation health effects have achieved a new level of knowledge; with advances in molecular biology and genetics, new understandings of radiation effects are advancing rapidly.

1. CHARACTERIZATION OF RADIATION EXPOSURE

The presentations and discussions at IRPA12 identified several areas related to characterization of both external and internal radiation exposure which demonstrate trends for the future in both computations and measurements. Advances are being made towards more sophisticated scientific and mathematical methods in computational procedures, such as Monte Carlo methods associated with the use of voxel phantoms and the application of more advanced statistical (notably Bayesian) approaches. Voxel phantoms will continue to increase in importance for use in external and internal dosimetry computations. Artificial neural networks and genetic neural networks are being developed and optimized for use in computations, and will grow in importance, particularly in the assessment of neutron doses.

Within the next few years, ICRP is expected to publish new documents on the occupational intake of radionuclides, which will apply the 2007 ICRP recommendations, with new voxel phantoms, decay schemes, and biokinetic models, including the human alimentary tract model.

Measurement technology continues to improve and the development of new instrumentation and dosimeters, calibration of dose response and characterization of the effective dose range of different dosimeters is required. Advances are expected to improve understanding of the uncertainties of dose measurement and assessments, such as anisotropic response for photons and neutron response.

From presentations in other areas, it is evident that increased analytical capabilities for internal dosimetry are required, e.g., during decommissioning of nuclear facilities, nuclear medicine, exposure to NORM, and as part of preparedness for triage in case of radiological events and other circumstances.

New developments will continue in biological dosimetry and will include evaluating the ability of biological dosimetry to contribute to dose determination in the low dose range. To promote these advances, intercomparison collaborations and networks for cooperation and assistance are expected to be developed.

Finally, it is clear that efforts must continue for the provision of advanced education and training in all aspects of dosimetry in order to provide an adequate supply of experts and improve continuity in this crucial scientific field.

2. BIOLOGICAL EFFECTS OF RADIATION

Impressive advances in understanding biological effects of radiation exposure at the molecular and genetic level were reported at IRPA12. Nevertheless Sievert lecturer Dr. Streffer expressed scepticism that a biological marker that can identify radiation damage with absolute certainty will be found soon.

The genome of a cell (i.e. the DNA) remains the primary target for radiation induced stochastic effects including cancers. The intrinsic mechanisms of effects on molecules, organelles and cells, particularly when radiation occurs at low doses and low dose rates, must yet be characterized to aid in understanding of their importance regarding health effects.

Several biological phenomena can modulate dose response and modify the dose response curve in the low dose range (<100 mSv):

- Bystander effect has been mainly studied in vitro but it may also lead to enhancement of radiation effects in vivo;
- Adaptive response is not a universal biological phenomenon with a number of limitations;
- Apoptosis is a very powerful cellular mechanism to eliminate damaged or no longer needed cells;
- Genomic instability has been observed in the progeny of irradiated cells after many generations of cell division.

The possible implications of these biological phenomena in the field of radiation protection still need to be determined. Response to low dose radiation is now being viewed from the perspective of integrated tissue responses rather than effects measured only on single cells.

At the organ and system level, the classical description of stochastic effects on cells and deterministic effects on tissues seem to be not so clear today because threshold values for deterministic effects seem to be lower than previously thought. Further advances in knowledge are expected in this area. For treatment of acute skin damage, grafting — including mesenchymal stem cells (MSC) in

combination with early surgery guided by dosimetry — provides fast pain relief and durable wound healing. Further investigation and development into both understanding deterministic effects and their treatment is expected.

An approach that can be applied to ionizing or non-ionizing radiation risk assessment is application of a new stochastic model of carcinogenesis involving breaking barrier mechanisms of a cell as a key feature of carcinogenesis. The barrier mechanisms (e.g., antioxidant defence, repair, apoptosis) represent the complex of cell responses to primary cell damage caused by exogenous and endogenous factors. This could lead to future collaborations on studies of the effects of both ionizing and non-ionizing radiation.

It appears more clear that exposure to radon, long known to be a carcinogenic agent, is the second most important cause of lung cancer after cigarette smoking. Therefore it is a challenge for radiation protection authorities to take immediate action to reduce exposure to radon in buildings and private homes. Continued advances are expected in understanding the synergistic effects of exposure to radiation (including radon) and chemicals (including cigarette smoke) because this continues to be an important topic of investigation.

In summary, ongoing research involving experimental, clinical and epidemiological investigations will contribute to improving knowledge of the biological effects of ionizing radiation. The results presented during IRPA12 indicate that LNT remains valid for prospective radiological protection risk estimation. However, for individual risk evaluation, individual factors (e.g. sex, age, lifestyle, exposure conditions, individual radiosensitivity) have to be considered. Epidemiology can probably not answer the open questions remaining regarding cancer induction in the low dose range. Radiobiological research may clarify some mechanisms involved and provide more scientific evidence for radiation protection.

OUTLOOK FOR THE RADIATION PROTECTION PARADIGM

The globally accepted radiation protection paradigm, which has been developed by ICRP over the years and which currently provides the foundation for nearly all national and international radiation protection regulation, is generally accepted; at the same time it is continually reviewed and modified. The new ICRP recommendations will be the basis for future revision of international radiation safety standards. It is anticipated that the traditional radiation protection paradigm will evolve into one for which a similar procedure can be used regardless of the exposure situation, a procedure characterized by optimization plus source related restrictions.

The future radiation protection paradigm will take into account the concept of an integrated safety regime covering all types of exposure situations, actual and potential, and all types of installations. Approval by the IAEA Board of Governors of a single set of Safety Fundamentals, cosponsored by all UN organizations and other specialized international institutions related to the topic, is a demonstration of this future integration, since this publication is at the top of a pyramid of international safety standards in radiation, nuclear, waste and transport safety. The International Basic Safety Standards (BSS) being revised already takes into account this integrated safety approach.

1. DEVELOPING THE RADIATION PROTECTION FRAMEWORK

The system of radiation protection is under continuous review and there is a need for an international safety regime. Therefore the process involved in this revision and evolution is crucial. On one hand, there has been enormous progress in the integration of different safety areas, particularly with intergovernmental endorsement of common safety fundamentals. On the other hand, such integration of different safety areas will not automatically result in the necessary interconnection required between different communities of regulators, industry, users and scientists. Emerging scientific results and challenges related to radiation protection should be shared among interested parties to build a common understanding of problems and possible solutions.

This vision may have a large number of consequences for many international organizations regarding cooperation in the development of a fully integrated globally applied safety regime. In the future, the new BSS will provide the basis for an integrated safety regime to protect people and the environment against radiation exposure from any type of exposure situation stemming from facilities and activities.

Implementation of an international safety regime challenges nations to build and maintain national infrastructures. To this end there is a clear need for support in developing countries to strengthen radiation protection. For instance, with regard to the control of radioactive sources, there is a need to promote better registration, control, traceability and disposal.

For developing radiation protection infrastructure, it is essential to educate and train relevant personnel to build competence, focusing in particular on regulatory body staff. Sustainability must be the objective, and knowledge management must be addressed to ensure retention of expertise.

Mixing national, regional and international resources will bring greater effectiveness and accelerate implementation of international standards and recommendations as well as promoting better sharing of knowledge and experience.

2. DEVELOPING PROTECTION POLICIES, CRITERIA, METHODS AND CULTURE

There is renewed interest concerning protection of the public and the environment. New techniques for environmental measurement and assessment are evolving because of growing demand related to decommissioning of facilities and remediation of contaminated sites, mainly uranium mining legacy sites. Radiation protection of the environment (non-human species) is not an urgent or important issue for most countries. However, policies, criteria and guides on this topic will be developed.

Regarding occupational exposure, there is a consensus that equilibrium in terms of regulation and awareness has been reached, leading to a decrease in dose values. The exception is in the medical arena, in which doses related to interventional radiology and nuclear medicine procedures (e.g. PET) appear to be increasing. There is an urgent need for improved training and promotion of safety culture.

Medical imaging has become the largest controllable source of radiation exposure. The patient dose is increasing in the case of both adults and children. Justification of practices is a key principle in this area. Efforts are required to educate and train medical staff in radiation protection principles and to develop a radiation protection culture as part of an overall safety culture.

It was noted that all interested parties, governments, regulators, workers, industries, medical professionals and the public have to be provided with adequate information and knowledge to protect themselves and others. Stakeholder involvement in the decision making process may help to build consensus and gain trust and confidence.

3. EMERGENCY PLANNING, PREPAREDNESS AND RESPONSE

An enduring lesson from past events is that consequences depend dramatically on steps taken to prepare an effective response. Advance arrangements must include clear authority and responsibility among relevant organizations, as well as criteria and policies for implementation of protective actions. Actions must be developed in collaboration with stakeholders and the public to ensure their engagement in advance. Effectiveness can be enhanced by using decision support tools which compile relevant information and help in assessing potential consequences of an event and providing alternative management actions. These tools must be developed and maintained in advance.

The re-emergence of nuclear power and the development of nuclear power in new countries must be accompanied by adequate emergency management capabilities. Developing, upgrading and improving nuclear or radiological emergency response programs is a long term commitment requiring a dedicated effort from all countries working together to develop a common strategy.

It was again emphasized that the possible occurrence of serious radiological events involving massive dispersion of radioactive substances requires special preparedness To respond adequately to such events will require the ability to assess and characterize the extent and level of contamination, to triage thousands of people and assess their levels of external and internal contamination, to cope with the possibility that national capabilities could be overwhelmed, and to have effective communication channels with the public to avoid and mitigate unnecessary alarm.

All countries should dedicate effort to developing and adopting a common strategy involving the identification of threats, planning, preparedness, response and recovery. Serious efforts to accelerate international cooperation are urgently needed. States must recognize that they may need assistance, and eliminate ‘donor/recipient’ mentality. It is now essential to elaborate and build upon existing arrangements and capabilities, such as the Notification and Assistance Conventions.

The post and recovery phases following an event are also receiving increasing attention. After an accident there will be a long term broad distribution of impacts and effects. This requires clear conceptual criteria and reliable assessments to deal with particular situations. Stakeholder engagement is important for the planning process and may facilitate successful decision making. With respect to medical response in emergencies, there is a need for further research and international consensus on diagnosis, treatment and long term follow-up criteria for potentially overexposed people. International assistance in medical response may be needed and pre-established arrangements are essential, including legal arrangements that simplify operations. It was recommended to

improve cooperation between national competent authorities and health authorities for preparedness and response under emergency conventions. Effective utilization of existing regional and international capabilities and arrangements for medical response were also identified as challenges.

OUTLOOK FOR RADIATION PROTECTION AND SAFETY IN PRACTICE

The radiation protection practitioners who attended the Congress generally expressed satisfaction with the current status of the global radiation safety regime. However, there is always an opportunity for improvement, and presentations and discussions identified many opportunities for future development in all subject areas relating to the practice of radiation protection.

A dominant issue is the education and training of a new generation of operational radiation protection experts and technical staff.

The implementation of radiation protection policies and programmes is not consistent over all users of radioactive materials and radiation producing devices. This provides an opportunity for future development and improvement in many areas. IRPA's new initiative on improving the radiation protection culture is an important opportunity for advancing and improving implementation in the near future.

There are additional specific future activities identified in each of the areas covered under 'Radiation Protection and Safety in Practice'.

1. NETWORKING IN RADIATION SAFETY

Regional networking is required decentralized complement to the actions of international organizations and regulatory bodies. Initiatives should originate from relevant stakeholders (operators, regulators, medical associations, and in general professionals). The future is open not only to the emergence of new networks, but also to the establishment of links between networks and possible creation of several networks of networks across geographical regions, topical issues and sectors of radiation protection.

2. LEGAL IMPLICATIONS OF RADIATION PROTECTION

Cooperation between lawyers, scientists and governments would result in benefits to everyone and should be reinforced in the coming years. There is a need to develop more unified and globally consistent legal obligations for compensating nuclear damages should they occur.

There is also a need for both precision and harmonization in the application of radiation protection standards, in particular with regard to optimization of radiation protection.

3. STAKEHOLDER ENGAGEMENT IN PRACTICE

Stakeholder participation in the decision making process is being recognized by some regulatory bodies. Engagement of stakeholders in decision making may be increasingly necessary in certain areas of radiation protection. It is expected that the IRPA Guiding Principles for Radiation Protection Professionals on Stakeholder Engagement will be valuable in this process.

4. RADIATION SAFETY IN NUCLEAR INSTALLATIONS

Substantial nuclear development is foreseen around the world over the coming decades, closely related to the challenges facing the world regarding energy and environment. This will lead to strengthening of radiation protection with greater harmonization of the global safety regime including full integration of radiation protection into the safety culture as a whole.

An additional challenge for the nuclear industry, as in other areas, is renewing and sustaining a competent radiation protection workforce. This requires support for education and training programmes and stewardship for emerging nuclear energy countries.

Sharing experience and international cooperation will be increasingly important in many activities associated with nuclear installations, e.g. decommissioning of facilities and remediation of sites, waste characterization. The implementation of obligations under the Joint Convention on the Safety of Spent Fuel and the Safety of Radioactive Waste Management will be essential.

About two-thirds of all nuclear power plants around the world are expected to reach and go beyond their original 30 year design lifetime within the next 10 years. Decommissioning and remediation is a growing field, and a key point to success is having an early plan. Advances can be expected in technologies and theoretical models applicable to radioactive waste characterization and enhancement of the radioactive inventory of certain residues types.

Ways to improve interaction with and involvement of stakeholders should be explored in relation to the siting process for waste management and storage facilities.

The international consensus reached under the aegis of international intergovernmental organizations on clearance, exemption and exclusion levels of radioactivity in commodities should be implemented.

5. NON-IONIZING RADIATION APPLICATIONS

While major effects of high level exposure have been identified and related interaction mechanisms are well understood, more research is needed on possible effects — mainly in the long term — of chronic low intensity fields and radiation. Studies on interaction mechanisms are of high priority.

With the availability of more and more powerful computation tools (hardware and software), significant advancements in dosimetry for all kinds of NIR are expected. Special effort should be devoted to microdosimetry.

The development of new technologies and sources gives rise to unprecedented exposure conditions, both in living environments and at workplaces. This requires studies to fully characterize the exposure, and an evaluation of measures to reduce exposure.

Protection standards have evolved over time towards a comprehensive and consistent protection system. The validity of present recommendations for safe exposure has been confirmed — with minor refinements — for both electromagnetic fields and optical radiation. However, given public concern and social pressure, the opportunity to complement science based standards with precautionary measures may be considered, taking into account possible consequences in terms of risk perception and increased worries.

6. MEDICINE

The increasing use of ionizing radiation for diagnostic and therapeutic purposes will result in a consequential increase in the global average population dose. In particular, new and rapidly evolving technologies are raising new and challenging radiation protection issues that should be addressed.

This will intensify the need for referral guidelines and appropriateness criteria for justification of medical exposures. The availability and use of such decision aiding tools should be promoted to reduce unnecessary radiation doses.

Major technological changes in the fields of radiation imaging and therapy will also enhance the need for QA programmes to optimize radiation protection, of patients, workers and the public. Protection of patients can be optimized by ensuring inter-alia that radiation dose is commensurate with the medical purpose of a procedure. It is expected that diagnostic reference levels will be increasingly applied and periodically reviewed as technology evolves. Particular focus is expected to be placed on paediatric patients and pregnant and breast feeding patients.

Computed tomography (CT) is becoming the most important contributor to medical exposure in diagnostic radiology, with a change in the pattern of usage

leading to an increasing proportion of procedures involving children and young people. Digital radiology (DR) is steadily replacing screen/film combinations and could lead to unnecessary radiation exposure of patients if appropriate training and procedures are not ensured.

Interventional radiology remains in continuous expansion. Radiation doses delivered during such procedures can be high enough to result in deterministic effects in patients (e.g. skin injuries) and even in staff (cataracts). Patient dose records allow for clinical follow-up when skin doses are too high. Particular emphasis will be placed on optimization of staff protection in the case of eye exposure.

Nuclear medicine is expanding through the growing use of PET, SPECT-CT, PET-CT cardiac diagnostic procedures, the introduction of new radiopharmaceuticals and the increasing use of radiotracers in surgical practices. This would imply the need to review and update radiation protection protocols to address protection of patients, staff and public, including facility design and site planning.

New and more complex radiotherapy techniques being introduced worldwide imply a challenge to maintain optimal target coverage with sparing of healthy tissue as well as prevention of errors and accidents.

Education and training of health professionals will remain crucial in radiation protection, and there is need for periodic review and updating of training programmes which are adapted to the particular needs of involved staff.

Harmonization and better coordination among regulatory bodies, health authorities specialized institutions, professional associations, scientific societies and academic institutions should be strengthened.

7. NORM IN INDUSTRY

For NORM industries, including uranium mining and processing, updated radiation protection procedures and regulations are urgently needed and can be expected in the near future. More than in other areas of radiation protection, there is a shortage of trained and experienced radiation protection professionals. Consequently, efforts must be directed to supporting and developing academic programmes in radiation protection issues related to NORM.

The disposition of legacy sites and decommissioning are serious issues both for uranium and other mineral mining and processing industries.

The oil and gas industries face particular challenges related to measurement of low activity or activity concentration, long decay chains and disequilibrium. Particularly challenging are the identification of radium isotopes, assessing Th/U in geological formations, and dating scales and contaminated soils.

Regulation of NORM is subject to a graded approach consistent with the optimization principle. The scope of regulation, including exclusion and exemption criteria, is being carefully considered so that regulations are not applied to all human activities.

8. OTHER APPLICATIONS AND PRACTICES

With the expected expansion of nuclear power and increases in the availability of nuclear medical applications, the transport of radioactive material will continue to increase in the foreseeable future. Additional efforts are being made by intergovernmental organizations and industries to overcome the denial of shipments by carriers. It is expected that improving knowledge about shipments will increase willingness to accept them. A better balance is needed in security requirements to ensure that materials are adequately protected during transport without creating disruptions to or burdens on carrier operations.

The benefits and risks of using ionizing radiation in security screening of individuals are being assessed, and justification of its use requires further discussion.

Advances in measurement techniques for radon exposure are expected. Reference levels are being discussed. The International Radon Project, sponsored by the World Health Organization, may be effective in identifying regions with high exposure to radon.

Exposure to cosmic rays of crews in commercial flights is an issue of concern. The participation of IFALPA at the Congress opened the way for the further exchange of information in this regard.

Proposals for space exploration beyond the orbit of the earth and the moon will place continuing demand on radiation protection experts to develop radiation measurement and dosimetry systems, and new shielding designs, as well as systems and programmes to assure adequate radiation protection for astronauts.

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J. REPUSSARD, IRSN
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Invited speaker:
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RC-6. Internal dosimetry. The science and art of internal dose assessment.	H. Doerfel (DEU)
RC-12. Early Biodosimetry Response: Recommendations for mass casualty radiation accidents and terrorism.	W. F. Blakely (USA)
RC-2. Cellular and molecular effects. Non-targeted biological effects of ionising radiation	O.V. Belyakov (FIN)
RC-7. Epidemiological methods on residential radon and cancer risk.	J.M Zielinski (CAN)
RC-3. Implementing the regulatory authority information system (RAIS).	K. Mrabit (IAEA)
RC-8. Managing Nuclear Knowledge.	Y. Yanev (BUL)
RC-4. Security of radioactive sources. Implementing the Code of Conduct and the export/import guidance.	P. Lardiez (ESP)
RC-9. Environmental surveillance programmes and dose assessment. Characterization of individual members of the public.	M. Lust (EST)
RC-10. ALARA and professional networks. Promoting optimisation of protection through professional networking.	C. Schieber (FRA)
RC-5. Diagnostic reference levels in medical practice.	M. Bourguignon (FRA)
RC-13. Consequence management of malevolent use of radioactive material. Strategies for enhancing security of radioactive materials.	C. Jones (USA)
RC-16. Implementation of the international obligations on emergency notification and response.	H. Aaltonen (FIN)
RC-17. Radiation protection in waste management and disposal. Implementing the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management.	A. Nader (URU)
RC-11. NIR measurements. Principles and practices of EMF characterization and measurements.	V. Cruz Ornetta (PER)
RC-14. Radiation protection in paediatric radiology.	C.L. Chapple (UK)
RC-18. Shielding of medical facilities. Shielding design considerations for PET-CT facilities.	J. Cruzate and A. Discacciati (ARG)
RC-19. Safe transport of radioactive materials. Security in the transport of radioactive materials.	R.R. Rawl (USA)
RC-20. Radiation protection in industrial applications of radioactive sources. Prevention of accidents in gammagraphy.	J. Croft (UK)
RC-15. Radon monitoring and control of radon exposure.	P.A. Colgan and A. McGarry (IRE)

TRAINING SEMINARS

Seminar 1. Radiological Protection of Patients Coordinators: C. Cousins, ICRP (UK) and E. Vañó, ICRP (ESP)	Panellists: C. COUSINS, ICRP (UK) E. VAÑÓ, ICRP (ESP) M. REHANI, IAEA C. BORRÁS, IOMP (ESP) A. BUZZI, UBA (ARG) P.MIRANDA, CALVO MACKENNA´S HOSPITAL (CHL) A. DURAN, UNIVERSITY SCHOOL OF MEDICINE (URY) C. MACCIA, CAATS (FRA) A. ROJO, ARN (ARG) P. ORTIZ-LOPEZ, IAEA
Seminar 2. Radiation Protection in NORM Industries, Including Phosphate Industry Coordinators: J. de Aquino (BRA), R. García-Tenorio (ESP) and D. Wymer (ZAF).	Panellists: A. CANOBA ARN (ARG) R. GARCÍA-TENORIO, UNIVERSITY OF SEVILLA (ESP) J. DE AQUINO, CNEN (BRA) B. BIRKY, FIPR (USA) J. HILTON (UK) J.MARCUS GODOY, IRD/CNEN (BRA) A. POFFIJN (BEL) F.P. CARVALHO, ITN (PRT) K. GEHRCKE, FEDERAL OFFICE FOR RADIATION PROTECTION (DEU)
Seminar 3. Radiation protection in the nuclear industry Coordinators: S. Saint Pierre, WNA (FRA) and E. Díaz (ARG)	Panellists: A. SANDÁ, NA-SA (ARG) J. DE OLIVEIRA MAGNO, ELECTRONUCLEAR (BRA) J. LÓPEZ VIETRI, ARN (ARG) E. SOLLET SAÑUDO, IBERDROLA (ESP) S. PÉREZ, ARN (ARG) M.L LIPS, GÖSGEN NPP (CHE) C.G. LINDVALL, BARSEBÄCK NPP (SWE) G. LARSSON, BARSEBÄCK NPP (SWE) F. HARRIS, BHPBILLION (AUT) S. SAINTPIERRE, WNA (FRA)

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Radiation is present everywhere in the natural environment and there are some industrial activities that lead to increased exposure to these natural sources. The use of radioactive material and radiation producing devices is on the rise in medical diagnostic and therapy procedures. These procedures generally benefit the patients involved, but also present risks to both the patient and medical personnel involved in the procedures. The protection of people and the environment from the harmful effects of ionizing and non-ionizing radiation, while permitting the development and use of radioactive material and radiation producing devices and technologies for the benefit of society, is a crucial international endeavour. This publication represents the official record of the 12th International Congress of IRPA, organized by the Argentine Radiation Protection Society in cooperation with the IAEA, the World Health Organization and the Pan American Health Organization, and held in Buenos Aires from 19 to 24 October 2008.

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