

Radiation Protection

ISBN 978-92-64-99013-5

**Radiation Protection
in Today's World:
Towards Sustainability**

© OECD 2007
NEA No. 6165

NUCLEAR ENERGY AGENCY
ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

ORGANISATION FOR ECONOMIC CO-OPERATION AND DEVELOPMENT

The OECD is a unique forum where the governments of 30 democracies work together to address the economic, social and environmental challenges of globalisation. The OECD is also at the forefront of efforts to understand and to help governments respond to new developments and concerns, such as corporate governance, the information economy and the challenges of an ageing population. The Organisation provides a setting where governments can compare policy experiences, seek answers to common problems, identify good practice and work to co-ordinate domestic and international policies.

The OECD member countries are: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Korea, Luxembourg, Mexico, the Netherlands, New Zealand, Norway, Poland, Portugal, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities takes part in the work of the OECD.

OECD Publishing disseminates widely the results of the Organisation's statistics gathering and research on economic, social and environmental issues, as well as the conventions, guidelines and standards agreed by its members.

This work is published on the responsibility of the Secretary-General of the OECD. The opinions expressed and arguments employed herein do not necessarily reflect the official views of the Organisation or of the governments of its member countries.

NUCLEAR ENERGY AGENCY

The OECD Nuclear Energy Agency (NEA) was established on 1st February 1958 under the name of the OEEC European Nuclear Energy Agency. It received its present designation on 20th April 1972, when Japan became its first non-European full member. NEA membership today consists of 28 OECD member countries: Australia, Austria, Belgium, Canada, the Czech Republic, Denmark, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Japan, Luxembourg, Mexico, the Netherlands, Norway, Portugal, the Republic of Korea, the Slovak Republic, Spain, Sweden, Switzerland, Turkey, the United Kingdom and the United States. The Commission of the European Communities also takes part in the work of the Agency.

The mission of the NEA is:

- to assist its member countries in maintaining and further developing, through international co-operation, the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, as well as
- to provide authoritative assessments and to forge common understandings on key issues as input to government decisions on nuclear energy policy and to broader OECD policy analyses in areas such as energy and sustainable development.

Specific areas of competence of the NEA include safety and regulation of nuclear activities, radioactive waste management, radiological protection, nuclear science, economic and technical analyses of the nuclear fuel cycle, nuclear law and liability, and public information. The NEA Data Bank provides nuclear data and computer program services for participating countries.

In these and related tasks, the NEA works in close collaboration with the International Atomic Energy Agency in Vienna, with which it has a Co-operation Agreement, as well as with other international organisations in the nuclear field.

© OECD 2007

No reproduction, copy, transmission or translation of this publication may be made without written permission. Applications should be sent to OECD Publishing: rights@oecd.org or by fax (+33-1) 45 24 99 30. Permission to photocopy a portion of this work should be addressed to the Centre Français d'exploitation du droit de Copie (CFC), 20 rue des Grands-Augustins, 75006 Paris, France, fax (+33-1) 46 34 67 19, (contact@cfcopies.com) or (for US only) to Copyright Clearance Center (CCC), 222 Rosewood Drive Danvers, MA 01923, USA, fax +1 978 646 8600, info@copyright.com.

Cover credits: South Texas (USA) and McClean Lake, Cogema.

FOREWORD

In 1993, the CRPPH held a workshop titled, *Radiation Protection on the Threshold of the 21st Century*. This followed the development and issuing of ICRP Publication 60, and was at the beginning of a period of adaptation, implementation and change. As such, the CRPPH felt that it would be useful to scan the horizon to see what types of issues could arise in the near-term future, and to study their possible implications. The intention was to help member countries to be better prepared to guide their national policy and application. As a result of this workshop, the CRPPH published, in 1994, a summary document titled, *Radiation Protection Today and Tomorrow: a Collective Opinion of the CRPPH*. In addition to the value that this work brought to NEA member countries, it also highlighted issues and areas to be further studied by the CRPPH. The collective opinion, in effect, became the blueprint of the Committee's programme of work for almost ten years. Since its publication, the CRPPH has completed reports and studies in all the major areas that were identified. The CRPPH contribution can be characterised by the four project directions described below.

Assessing the implications of radiological protection science

The 1994 collective opinion identified advances in radiological protection science as possible vectors for future change in radiological protection policy. In its 1998 assessment of radiological protection health sciences, the Committee further elaborated these challenges and highlighted the need to articulate the necessary ties between radiation biology, epidemiology and the fundamental principles of radiological protection.

Embracing stakeholder involvement

One of the key issues for the CRPPH, that was in fact identified in the 1994 collective opinion and has been progressively highlighted in open discussions within the radiological protection community, is the involvement of stakeholders in decision-framing and decision-making processes. Through reports and discussions, in particular the three Villigen workshops (1998, 2001, 2003), the CRPPH has demonstrated the importance of stakeholder involvement to enhance the quality and effectiveness of decisions in complex radiological protection situations.

Fostering exchange of experience

The 1994 collective opinion identified the value of enhancing the Committee's efforts on the International Nuclear Emergency Exercises (INEX) and the Information System on Occupational Exposure (ISOE), which had both built upon the Committee's work carried out during the late 1980s. The CRPPH has continued to develop these programmes, which benefit both member and non-member countries. By way of example, INEX involves 35 countries on average per exercise and ISOE provides for the exchange of data among 91% of operating commercial nuclear reactors worldwide.

Partnering with the ICRP

The importance of the International Commission on Radiological Protection (ICRP) to governments and radiological protection practitioners was highlighted in the 1994 collective opinion. Since then, the CRPPH has continued to pay significant attention to the ICRP's recommendations and has served as a partner to the ICRP, particularly in the open process implemented for revising its recommendations.

In late 2004 the NEA published its Strategic Plan (2005-2009), and as part of this effort all the NEA standing technical committees, including the CRPPH, reviewed their mandates for possible updating. At the same time, the ICRP had begun to develop new recommendations. In this atmosphere of renewal, it seemed very appropriate for the CRPPH to once more begin to identify topics and areas that, in the mid- to long-term future, would or could have significant influence on radiological protection policy, regulation and application. The ultimate objective of this work was to develop a new CRPPH vision that would provide the Committee with programmatic direction for at least five to ten years. To begin this undertaking, the CRPPH held a topical session during its 2004 annual meeting, during which outside experts in radiological protection presented their views on challenges in the areas of policy, regulation, science and implementation. Subsequently, the CRPPH brought together a broad group of stakeholders, from within and without the usual CRPPH circles, to hold a brainstorming meeting. Finally, the CRPPH mandated the Expert Group on the CRPPH Collective Opinion (EGCO) to carry this work forward.

This report thus represents a continuation of the 1994 CRPPH collective opinion. It is intended to assist decision makers at all levels (government, industry, NGOs, individuals) to identify issues of concern sufficiently in advance to allow them to be appropriately addressed within their relevant contexts. While this report does not aim to suggest solutions to the issues and areas that it identifies, it does aim to highlight the areas that may pose

challenges in the future. The CRPPH will use this report as a key input to its future programme of work, such that possible approaches to these challenges can be identified discussed and considered for national implementation.

TABLE OF CONTENTS

Foreword	3
Executive summary	9
Introduction	19
Where are we now?	21
Scientific challenges to the existing paradigm.....	21
Social changes and their relevance to radiological protection	23
Experience and lessons learnt	25
Historical perspective.....	27
Recent trends.....	30
Future development of RP principles.....	31
Key issues for the future of radiological protection application	33
Balancing local, national and international needs.....	33
Applying radiological protection principles to public and worker protection	40
Maintenance of radiation protection and safety culture in the workplace.....	43
Application of radiological protection principles in specific contexts.....	46
Maintaining competence, transmission of inheritance.....	60
Conclusions	63
References	65
Qualities of the CRPPH	71

EXECUTIVE SUMMARY

Introduction

There is a broad consensus among radiological protection professionals that the current approach to radiological protection provides a solid basis for establishing regulatory programmes that promote and assure effective safeguards for the protection of the public, workers and the environment from the deleterious effects that can arise from the use or handling of sources of radiation. The existing principles, policies, standards and regulations are the result of a continuum of incremental enhancements, incorporating state-of-the-art scientific developments, social evolution, and experience as the system is applied and new challenges arise. This report reviews the changes over the past 10 to 15 years, examines where we are today and identifies the key challenges for the future.

Where are we now?

The capability to assess radiological risks continues to progress as a result of scientific research. Historically, the complexities of radiation biology and cancer genesis have required assessments to be primarily based on “macroscopic” epidemiological studies of exposed populations of humans, animals, insects and plants. However, more recent “microscopic” studies from modern cellular and genetic biology have significantly contributed to our knowledge of how humans and the environment react to exposure to various sorts of ionising radiation, and under different types of exposure situations.

Over the past 10 to 15 years, the results of large and pooled epidemiological studies have tended to support the broad view that the relationship between radiation dose and risk is more or less linear down to increasingly low levels (currently at about 100 mSv). While these studies have significantly reduced the range of uncertainty in risk estimates, they are reaching their limits due to the size of the study populations necessary to statistically demonstrate evidence of risk at lower exposure levels. At the same time, radiation biology studies have provided additional specific evidence of various radiation-induced effects (e.g. bystander effects, non-cancer effects, adaptive response) and of

possible mechanisms for producing these effects at the cellular level. These suggest that our current approach to risk assessment, assuming a linear, no-threshold model and additivity of all exposures, may not be an adequate approach in all cases. These findings remain, by-and-large preliminary, and further study is needed. However, they raise questions that could have implications for radiological protection (RP) policy, regulation and application and as such, they need to be considered in decisions regarding the management of radiation risks.

In addition to these scientific developments, the evolution of society has also impacted on radiological protection. Today, many groups and individuals in different countries want to be involved in discussions and decisions affecting public health and environmental protection. Stakeholders question the role of science and authorities in decision making, and demand accountability in decisions regarding the management of risks. The importance of this trend for radiological protection decision-making was recognised as an emerging challenge by the CRPPH in its 1994 Collective Opinion. Today, the need to involve stakeholders has affected the way that the RP principles of Justification, Optimisation and Dose Limitation are viewed. It has also affected the role of the RP professional in risk assessment and management and, for some decisions, has highlighted the relative importance of case-specific circumstances over harmonised, internationally accepted criteria. While the central importance of stakeholder involvement in addressing many risk situations is now widely accepted, the next step will be to optimise structures and processes to facilitate such participation. Environmentalism has also continued to grow, to the point where increasingly, and at many levels, there is a link between good public health and a “healthy” environment. Much of the public demand for a clean environment is thus formulated on the basis of “quality of life” and “well being”. These notions, both as social values and as scientific facts, are central to many of today’s decisions and decision-making processes.

The implementation of radiological protection over the past 10 to 15 years has resulted in much experience and in many “practical” lessons learnt. It is increasingly clear that some level of control can, and should, be maintained over all radiation sources and exposure situations. A corollary to this is that the management of risks, while fitting within a generic framework, will be largely driven by the specific circumstances under consideration. Of the practical lessons drawn from experience, two particular “problem” areas stand out: these are the segregation of situations as either Practices or Interventions, and the application of the concepts of Exclusion and Exemption. Since 1994, experience has shown that there is no value in maintaining separate approaches for Practices and Interventions. The response to intervention situations can also be controlled and the possibility of undertaking actions to reduce exposures brings

the focus more towards the process of optimisation of protection, with the caveat that, in so far as is possible, exposures should be maintained below some “reasonably chosen” upper bound (i.e. to prevent deterministic effects, to reflect industry good practice, to recognise the magnitude of natural exposures and the efforts necessary to affect change, etc.).

The necessity to consider case-specific circumstances has led some decisions away from the strict use of “universal” or “internationally-harmonised” exclusion and exemption criteria found in the current literature. This is very clearly seen in situations involving the release of radioactive materials from regulatory control. The current approach has been to identify generic levels below which regulatory actions are not considered warranted, and to “exempt” exposures below these levels. While generic figures (the value of 10 $\mu\text{Sv/a}$ is often cited) have been of use in decision making under some circumstances, their widespread application for the release of radioactive materials (solid, liquid or gaseous) from regulatory control has not been universally accepted. Rather, for the release of sites after cleanup; the release of materials for disposal, recycling or reuse; or the setting of discharge limits; local, site-specific discussions to identify the optimum protection solution, perhaps using standardised values as a guideline or starting point, are increasingly the norm.

Evolution of the RP system: historical perspective and recent trends

The principles of radiological protection were originally developed by radiologists and radiation researchers to protect themselves from the harmful effects of radiation, which emerged early in the 20th century. Over time, these principles matured to reflect the need to protect patients, workers, and eventually the public. Now, extension of international RP principles to explicitly protect the environment is being developed. Throughout this development, radiological protection has pragmatically adjusted to appropriately address new and arising issues, broadly basing its direction on consideration of equity (the limitation principle), precaution in the face of uncertainty (the optimisation principle) and responsibility (the Justification principle). The ICRP has documented its general recommendations in a series of reports, beginning with Publication 1 in 1959. Over time, emerging circumstances (e.g. radon exposures, accident situations), new science (e.g. new a-bomb survivor dose estimates), and/or social evolution (e.g. prudence in the face of scientific uncertainty) have led to the adaptation of the general recommendations, with new general recommendations being developed on three occasions; Publication 9 (1966), Publication 26 (1977), and Publication 60 (1990).

Until the issuing of ICRP Publication 60 and somewhat thereafter, the radiological protection community generally viewed radiological protection as the development and implementation of radiological protection principles, standards and regulations based on scientific evidence. However, increasingly over the past 15 years or so, the need to involve stakeholders in risk management has altered the situation and a view is emerging of radiological protection as a social judgement informed by sound scientific knowledge. The CRPPH Villigen workshops, which explored stakeholder participation, highlighted the premise that the radiological protection community should primarily focus on “integrating radiation protection into social decisions, not integrating social decisions into radiation protection”, and provided concrete lessons and experience in this area.

Taken together, pressures from social evolution and implementation experience suggest that future consideration of radiological risk assessment and management will be increasingly influenced by stakeholders, and that prevailing circumstances will be strongly taken into account, perhaps leading to specific, local solutions. The balance between internationally harmonised approaches and local specificity must therefore be a central issue in the future development of radiological protection principles.

It should also be noted that the ICRP has changed its approach to the development of new principles and recommendations, influenced strongly by recent social evolution. Until the 1999 ICRP open paper on controllable dose, recommendation documents were developed in a rather closed, expert-group fashion. With the opening of the development process to broad dialogue and comment, the process has significantly changed, in what will most likely be an irreversible fashion. The “new” approach that the ICRP has initiated for the development of its new recommendations will undoubtedly have an effect on the roles of organisations other than the ICRP in the development, interpretation and implementation of radiological protection programmes based on multi-partner discussions. Already the CRPPH has adapted and played a key role in coordinating and facilitating dialogue between the ICRP and the wider radiological community.

Key issues for the future of radiological protection application

Advancement in radiological protection science, increasing experience of implementing radiological protection, and social evolution all condition the way in which radiological protection principles are interpreted and implemented. In reviewing the current situation, the CRPPH feels that the evolution in these areas will increasingly challenge our current approaches to radiological protection policy, regulation and application and will demand new perspectives and new thinking.

The need for new perspectives and thinking does not arise from any particularly significant change coming from science, experience or society. Rather, the smaller, incremental changes in these three areas as a whole suggest the need for change. It is possible to characterise how certain types of situations will be affected and will need to be viewed in order to provide the most appropriate radiological protection under the prevailing circumstances.

In this context, the CRPPH has identified four key areas where new approaches will be needed. The first area, which reflects challenges at the policy and regulatory level, concerns the balancing of local, national and international needs in order to identify and implement sustainable radiological protection solutions. The second area, which relates to implementation challenges, concerns approaches to identify appropriate protection for workers and the public. The third area concerns the implementation of radiological protection principles in four specific circumstances: contaminated areas and materials; decommissioning and dismantling; medical exposures; and radiological emergencies and malevolent acts. The fourth area, which reflects the rapid expansion of radiation uses, concerns the maintenance of competence and the intergenerational transmission of knowledge.

Balancing needs: international, national and local needs

In the future, there will be a growing need to more explicitly consider the balance between internationally-agreed, harmonised approaches to radiological protection, and locally-driven, case-specific solutions. This can be characterised as a balance between the need to take a broad, holistic approach, and the need to apply the precautionary principle to the specific case under consideration.

The holistic approach to risk management attempts to consider all relevant aspects of a situation in order to achieve a sustainable, coherent solution. Public health is intrinsically a subject that must be viewed holistically, as is the development of an explicit system of radiological protection for the environment. A further complication is the issue of inter-generational risk transfers, which are inherent when dealing with the long-lived nature of many radiological risks. Clearly, there are conceptual, scientific and social challenges to the development of any over-arching approach to risk identification and management. Real challenges exist today, such as addressing NORM or combined effects (e.g. smoking and radon exposure). Although scientific studies will surely provide new and innovative approaches to quantify and compare risks, the key to addressing such situations continues to be the use of effective social dialogue processes informed by sound science. The radiation protection community must look to the experience in other fields (e.g. chemical, traffic, other industrial facilities, etc.).

Almost in counterbalance to the holistic approach is the need to apply the precautionary principle in specific circumstances. Broadly, where expressed in statutes, this principle suggests that, in the face of risk, the lack of full scientific understanding should not be used as a justification not to act in a proportional, cost-effective fashion. While the science of radiological protection continues to advance, there remain uncertainties, the most practically significant of these being the quantification of risks at low doses. In view of the uncertainties, application of the precautionary principle suggests that protective actions should be proportional to the risks in question, and cost effective. Both of these notions are social judgements which require discussion of the radiological risk, informed by the relevant scientific facts, in order to identify the most socially appropriate, cost-effective balance. Developing explicit approaches for the radiological protection of the environment will be a significant challenge in terms of appropriately identifying this balance. Stakeholder involvement in discussions will be increasingly essential in identifying solutions, and this could have profound effects on radiation protection policies, regulations, application and structures.

A concrete example of the difficulties that can arise when balancing needs is the use of national and international numerical norms and standards. Designed to be applied in a generic fashion, numerical criteria are often expressed such that “below a certain criteria specified actions should not be taken”, or “above a certain criteria specified actions should be taken”. This approach can pose problems when applied to specific, local situations, particularly if the stakeholders do not agree with the judgements that are implicitly or explicitly included in the selection of the numerical criteria.

Protecting the public and workers

The need to balance the local, national and international aspects of decisions will be practically manifest in discussions regarding the protection of the public and of workers. Because of the inherently different nature of the stakeholders in these two protection situations, the methods used to achieve the necessary balance will be different. In the case of public protection, the approach could focus on improving the transparency of decisions and on building and maintaining citizen vigilance. In the case of worker protection, the appropriate balance could be achieved by means of a vibrant, living safety culture.

In the context of radiological protection of the public, balancing of multi-dimensional needs is increasingly achieved through inclusive risk governance, transparency of decisions and citizen vigilance. These concepts are complementary in the sense that inclusive risk governance represents the

“public structural process” that governments put in place to address risks, and citizen vigilance represents the “private check-and-balance” that affected populations put in place to assure that risk identification and management meets social expectations. This represents a public/private partnership that is inherently multi-disciplinary, and that uses scientific “tools” to inform dialogues, debates and deliberations in the face of uncertainties. This approach may present significant legal and structural challenges to regulatory authorities, and may force trade-offs between local and national level perceptions (e.g. of risks, of benefits, of costs, of priorities, etc.).

In the context of radiological protection of workers, maintenance of an active safety culture is central to ensuring worker protection. Taken broadly, safety culture refers to a “questioning attitude” with regard to whether enough has been done to reduce exposures. Inherently, this takes into account the specific situation under consideration, but the trend is increasingly towards integration of radiological protection issues within the framework of overall worker health and safety and risk management.

A particular challenge presented by the current circumstances is that the profession of radiological protection is becoming increasingly stretched. The rapid expansion in medical and industrial uses of radiation has put pressure on existing professionals to cover all aspects, and has challenged the wide range of users who must be conversant with the risks associated with radiation use. In the case of the nuclear industry, the shrinkage over the past two decades has not attracted new professionals to replace the increasingly aging workforce. The challenge now is to increase the number of trained professionals coming through the university and professional education pipelines, while at the same time developing more effective training methodologies in the workplace. This evolution will need to address expansion of medical and industrial uses of radiation, as well as possible new growth in the nuclear industry. The maintenance of experience and experience exchange processes such as the Information System on Occupational Exposure (ISOE) will be essential. New nuclear reactors (e.g. Generation IV) will need to base their design and operational objectives on current “state-of-the-art” technology and processes.

Radiological protection in specific circumstances

Four specific practical situations have been identified as being in need of particular attention in the context of current RP science, experience and social evolution: these are (a) the release of contaminated areas and materials; (b) decommissioning of nuclear facilities; (c) medical exposures; and radiological emergencies and (d) malevolent uses of radioactive materials.

- (a) Contaminated areas and materials represent a particular challenge to the system of radiological protection. The ICRP publication 60 doctrine recommends that existing situations (e.g. high natural background or residual contamination from former, unregulated practices) and post-accident situations should be considered as Intervention situations, and thus addressed through a protection system that differs from that applied to a fully controlled practice. This difference in approach has not been easily explained to the affected populations, and has been difficult if not impossible to implement. Similarly for contaminated materials, universal radiological criteria for trade in food and commodities have been developed after much debate, yet have not truly been universally applied. These situations are key examples of the difficulties in balancing international harmonisation, particularly of numerical criteria, and the need for local, case-specific solutions. Where environmental contamination is involved, the trend seems to point towards broader considerations, such as avoiding environmental accumulation, than simply dose to humans or non-human species. The CRPPH's experience in stakeholder involvement and nuclear emergency management will most certainly be applicable to such situations as they are addressed in the future.
- (b) A specific application of approaches to dealing with the release of areas and materials is the decommissioning of nuclear installations. All nuclear power plants, as well as other nuclear installations and research reactors, eventually reach the end of their useful lives. Decommissioning is the process through which radiological hazards are optimally removed, and the facility is released from regulatory control. Although some sites may be reused for other nuclear-related activities, and the use of some sites may be restricted due to residual contamination levels, in most cases the aim of decommissioning is unconditional site release in the longer term. The process leading to site release will be driven, at least in part, by stakeholder interactions, and will include the input of plant workers, populations living in the area, and local municipal governments. As such, solutions will need to balance national (and perhaps international) considerations against the concerns of local stakeholders. Coming to agreement on the perceived costs and benefits of various levels of cleanup activities and on long-term use assumptions will be key to achieving accepted solutions. Current trends suggest that, in general, early decommissioning is the preferred option, as opposed to deferred dismantling or long-term entombment. Over these shorter timescales, the opportunity to reduce exposure rates through radioactive decay is less, placing greater demands on good radiological protection practice and the optimisation process.

- (c) Under social pressure and rapid technical evolution, the medical use of radiation is growing, and is today the largest man-made source of radiation exposure. The latest UNSCEAR report (UNSCEAR, 2000) documented a steady increase in the last decades of the per caput number of medical procedures using radiation, with an associated increase of collective exposure. In addition to increases in the number of procedures, the dose associated with some of the newer interventional procedures is also higher. Changes in the patterns of health care levels in developing countries due to economic development, as well as the advances in technologies in developed countries, foreshadow further increases. Rapid advances in techniques and equipment for the diagnostic and therapeutic uses of radiation tend to leave regulatory control and professional training lagging behind current practice. National regulatory approaches and structures for medical exposures can vary quite widely from country to country, but there seems to be a clear need for dialogue among regulatory, practitioner, industrial and patient stakeholder groups to develop appropriate mechanisms to assure that exposures are optimised.
- (d) A challenge that has recently emerged is that of responding to malevolent acts involving radioactive materials. Because of the likelihood that such actions would be aimed at urban environments and large populations, the challenges presented are both technical and social. From the technical standpoint, addressing public health needs poses some significant issues. These include large-scale internal dose assessment, resources to treat 10s to 100s of highly-irradiated victims and contamination characterisation in complex urban environments. From the social standpoint, many people receiving little or no exposure would demand some reassurance that their health had not been affected leading to the need for exposure screening, long-term health follow-up and epidemiological studies. Recovery and rehabilitation issues will be of the utmost importance including, for example, clean-up of public and private areas and compensation. Together, these issues will put significant pressure on public authorities, and will challenge the faith and trust that citizens have in their public bodies. Experience from nuclear power plant emergency exercises, such as those organised through the INEX programme, will be applicable, at least in part. In addition, the CRPPH's experience of stakeholder involvement through the Villigen series of workshops will also be relevant, as will the post-Chernobyl rehabilitation experience. There will be a need to "translate" these experiences into the specific, preparedness and post-event context.

Maintaining and transmitting competence

Beyond the need to increase the flow of trained professionals, and to better train practitioners, there is also a need to manage radiation protection knowledge. This refers to the contextual experience that accompanies lessons learned and experience, so as to minimise the need to “relearn” lessons. Knowledge management by leading international organizations will be greatly needed to prevent the loss or dilution of the knowledge base, and to prevent the emergence of gaps between generations, or between developed and developing countries. The CRPPH will be expected to contribute to filling knowledge gaps.

Conclusions

Looking back over the past 10 to 15 years, the CRPPH has played a valuable role in assisting its members to understand the challenges of radiological protection and in contributing to the development of workable solutions. In particular, the dialogue of CRPPH with the ICRP during the development of its new recommendations has been widely appreciated. While the basis of radiological protection science has not altered and the fundamental principles remain intact, there has been a social evolution and a number of events that have somewhat shifted the way that radiological protection is implemented. These changes are impacting on the roles of radiation protection professionals within organisations and society, and they present challenges to the profession going forward. The CRPPH has identified a number of key issues for the future of radiological protection application. These include the need to balance local, national and international considerations, the need to involve the public and workers in radiological protection and the need to maintain competence and transmit radiological protection knowledge to future generations. In addition, four specific practical situations have been identified as requiring further consideration: these are the legacy of contaminated areas and materials, the decommissioning of nuclear installations, the increase in medical exposures and radiological emergencies, including malevolent acts. In the coming years, the CRPPH will work with its members to advance these issues and to ensure that the application of radiological protection continues to build on the solid foundation already established.

INTRODUCTION

There continues to be a broad consensus among radiological protection professionals that the current approach to radiological protection provides a solid basis for protection of the public, workers and the environment from the harmful effects of ionising radiation. However, principles, policies, standards, regulations and good practice reflect a continuum of incremental changes, incorporating state-of-the-art scientific developments, social evolution, and experience as the system is applied and new challenges (e.g. radon, accidents) arise. The magnitude of these developments over the past 10 to 15 years, although not due to any single change, warrants a review of where we are today, so as to better foresee how to move forward.

Such time-to-time reviews are one of the key roles of the CRPPH. These serve to “take the pulse” of the system of radiological protection, particularly in terms of its relevance to today’s needs in today’s world. The last such exercise resulted in the 1994 CRPPH Collective Opinion, which served as a “road map” for the Committee’s work over 10 years. That document was motivated broadly as a result of the release of new ICRP recommendations, Publication 60, which was itself developed at least in part based on new risk estimates from the study of the a-bomb survivors at Hiroshima and Nagasaki.

While at that time a key motivation for change was new scientific results, there is no single, significant motivating force today. Instead, there have been several drivers of evolution. Advances in radiological protection sciences continue to raise significant questions that may challenge our current understanding of risk and approach to risk assessment. Ongoing epidemiological studies suggest possible new results (e.g. non-cancer diseases, response to chronic exposures), while radiation biology is exploring new mechanisms of radiation effects (e.g. bystander and non-targeted effects, genetic instability, individual sensitivity). Together, these may in some cases challenge the simple, universal application of “dose is proportional to risk” models that have been used for so many years. Social evolution has also pushed the system to change, with stakeholder involvement and broader participatory democratic processes becoming increasingly “main stream”. This, in some cases along with the lack of trust in technology and institutions, is changing the way the objectives of

radiation protection are viewed. Finally, experience with implementing the current system has proven to be a useful teacher. It has been difficult to implement some aspects of the system, such as the artificial distinction between “practices” and “interventions”, or the application of “universal criteria” for exclusion and exemption. Alternative approaches have been developed to address situations presenting difficulties, for example site-specific approaches to release of materials and sites, or use of emergency intervention levels for planning only. All these pressures, both independently and in a linked fashion, have sculpted the system of radiological protection to its current form, which profoundly affects how ongoing and emerging issues will, and can be addressed in the future.

From this understanding of where we are, and how we arrived here, it is possible to look forward to identify the new issues that may emerge as challenges, or the ongoing issues whose handling must evolve as a result of changes. The major concerns can be summarised as being in the areas of public health, the environment, and sustainable development. In general, there is a strengthening link between the quality of life (e.g. health, quality and accessibility of services, etc.) and the quality of the environment (e.g. for today and for tomorrow). Beyond the need to manage radioactivity in the environment and maintain any resultant exposures ALARA, there is growing attention as to how the current approach to protection can most appropriately and sustainably preserve the quality of health and the environment in the long term. Addressing such questions calls for a holistic approach, involving individuals and the system, at the national and international level. By its very nature, this must strongly involve local views. It is here that the RP professional has the opportunity to bring scientific expertise to the service of issues and concerns. In addition to these challenges to policy, there are many challenges to application, such as technological advances in the medical field that are significantly increasing exposures; the possibility of malevolent actions using radiological or nuclear materials could cause wide spread contamination and exposure, and public panic. Finally, for our future well-being, it is necessary to effectively address issues of education, safety culture and maintenance and transmission of knowledge. Details of these issues, why they present challenges, and particular aspects to study, are highlighted in the following sections of this report.

WHERE ARE WE NOW?

Having a clear understanding of where we are today, and of the pathways that scientific and social evolution have taken to lead us here, it is possible to project into the coming five to ten years to see what may be the most significant policy, regulatory and operational challenges. While it is not certain that such future challenges will arise, the process of looking ahead, and of building knowledge and approaches to improving risk assessment and management will help assure that governments are best placed to protect the public, workers and the environment for any such challenges posed by exposure to ionising radiation.

Scientific challenges to the existing paradigm

The capability to assess radiological risks continues to progress as a result of scientific research. Historically, the complexities of radiation biology and cancer genesis have required assessments to be primarily based on “macroscopic” epidemiological studies of exposed populations of humans, animals, insects and plants. However “microscopic” studies from modern cellular and genetic biology have significantly contributed to our knowledge of how humans and the environment react to exposures to various sorts of ionising radiation, and under different types of exposure situations. It is a continuing challenge to bridge radiobiology and epidemiology studies of risk assessment to assist decisions regarding risk management in the face of scientific uncertainties. This was identified as an issue in the 1994 CRPPH Collective Opinion:

However, there is a growing feeling that future scientific advances in biology might result in other breakthroughs in fundamental scientific knowledge capable of affecting radiation protection principles and doctrine. These advances could lead to changes in the dose-effect relationship and the risk models, and provide genetic analysis techniques capable of specifically identifying radiation-induced tumours above the general background of cancer incidence.

At the microscopic level, research over the past ten years has provided additional specific evidence of various effects, for example bystander effects, non-cancer effects, adaptive response, and possible mechanisms at the cellular level, but many questions remain:

- There is increasing scientific evidence that the summing of different types of exposure (e.g. internal and external, high LET and low LET, doses to different organs, etc.) is questionable in terms of the ability of the sum, characterised in Sieverts, to correctly represent overall detriment in all cases.
- There is increasing scientific evidence of non-targeted, adaptive response and delayed effects seen at the cellular level. It is not clear, however, if these translate into a “practical” threshold of dose below which risk is zero (or even positive).
- There is increasing scientific evidence that some individuals may be genetically more susceptible to radiation-induced cancer than others. It is not clear, however, how significant this enhanced susceptibility might be, or in what fraction of the population it occurs.

At the same time, large and pooled epidemiological studies tend to support, from the macroscopic level, the broad view that the average risks are more or less linear down to increasingly low exposure levels (currently at about 100 mSv). While epidemiological studies have significantly reduced the range of uncertainty in risk estimates, they are reaching their limits in terms of the size of the study populations necessary to statistically demonstrate evidence of risk at lower exposure levels. In addition, very recent epidemiological studies suggest the existence of radiation-induced non-cancer risks, although these have not been found to be statistically significant.

These findings remain by-and-large preliminary, and in need of further study, but they raise many questions that could have significant implications for radiological protection policy, regulation and application. Thus research suggests that our current scientific concept of dose and its relationship to detriment could be significantly challenged, and may need extensive rethinking. The relationship between radiological protection science and radiological protection policy, as scientific knowledge advances, will clearly need to be studied further.

Another type of “pressure” on the system, which calls for further scientific understanding, concerns “who we are protecting”. Currently, the science supports risk assessment for the “average” individual. But data are continually being collected on more distinct groups (e.g. by age, by sex, by genetic predisposition, etc.), genetic tests and genetic susceptibility are advancing, and

models and computer modelling abilities have vastly improved to be much closer now to “individual” modelling. Data on risk does not support the “estimation” of an individual’s risk, but there is growing social expectation that this “is” or will be the case. As a result, it will be important for the RP community to explicitly consider if specific groups should be specifically protected? This could consequently affect how protection objectives are viewed, and how optimisation is performed.

The work of the CRPPH Expert Group on the Implications of Radiological Protection Science (EGIS) provides further details into the implications that ongoing scientific research in these areas could have on radiological protection policy, regulation and application.

Social changes and their relevance to radiological protection

Society and its approaches to protection against ionising radiation have significantly evolved over the past decades. Historically, radiological protection was born before the second world war of the medical community’s desire to protect itself and its researchers from the harmful, deterministic effects of ionising radiation, and based on the possibility of genetic effects which had been identified in fruit flies. Focus shifted, as a result of Manhattan project atomic weapons research, from medical aspects to more the physical description of energy transfer and absorption, and to increasingly sensitive detection of all types of radiation. Early norms for radiation exposure were developed, with deterministic effects being the key focus. However, after the explosions at Hiroshima and Nagasaki, the cancer-causing potential of exposure to ionising radiation was highlighted, and this has become increasingly central to radiological protection doctrine.

Beginning with the social upheavals of the 1960s, the barriers that once surrounded risk assessment and management decisions and decision-making processes have been increasingly disappearing. The days when well-meaning public officials and technical experts could, to the best of their judgement, make public-protection decisions in isolation are gone. Today, many groups and individuals in different countries are interested in being involved, at various levels of participatory democracy, in discussions and decisions affecting public health and environmental protection issues. Individual members of the public subject to particular risks, local and national groups, associations, NGOs, and even federal, state and local government offices not directly responsible for decisions often feel that their views should be taken into account during any decision making process, and that their concerns need to be addressed. These individuals and groups, as well as the responsible regulatory authorities and, if applicable the risk-causing facility/process operator, have come to be known

collectively as Stakeholders. Stakeholder involvement in decision-framing and decision-making processes involving any and all public, worker and environmental risks is increasingly common in today's world. Stakeholders question the role of science and authorities in risk decision making, and demand accountability in decisions regarding the management of risks. This was already recognised as an emerging challenge in the 1994 CRPPH collective opinion.

Moreover, the social dimension of radiation protection decisions, both in managing work force and in coping with the impact of large scale nuclear operations, including possible accidents, is now more fully recognised. It requires the development of better mechanisms for the involvement of social parties and the public in the decision processes and the search for a closer integration of the management of radiation risks with that of other hazardous substances or situations.

The growing importance of stakeholder involvement in RP decision making has affected the way that the principles of justification, optimisation and limitation are viewed, the way the role of the RP professional in risk assessment and management is viewed, and the relative importance of case-specific circumstances in relation to harmonised, internationally accepted criteria. While the central importance of stakeholder involvement in addressing many risk situations is now widely accepted, the next step will be to optimise structures and processes to facilitate such participation.

The growing interest in risk decisions reflects many different aspects of social and scientific evolution. For example, the media, and our information society in general, have made information on risks much more available to everyone. At the same time, the technological promises of post World War-II advances have often not lived up to initial claims, breeding some scepticism of science and public institutions. With this has come the increasing realisation that science is only part of "the truth" with respect to judgemental decisions affecting such things as "safety", "security" and "the protection of health and the environment". Increasingly, social values emerge as being as influential as scientific facts with respect to decisions. At the same time, technology and the availability of information have made it possible for an individual to much more actively manage their own risks.

Along with these changes, which broadly reflect the individual's evolving place and role in society, the world has become much more of a "global entity", thus requiring global, social harmonisation in a broad sense. The notions of sustainability and intergenerational awareness have introduced a much longer view in any planning discussions. This is particularly relevant in terms of the perspective on what is meant by "progress", on the "margin" within which work can/should take place, on the objectives for projects, and on the expected speed

of projects. These global aspects suggest that some level of international harmonisation is needed.

Yet, as these global issues become more widely recognised, there is also a trend that local contexts are increasingly important to decisions regarding radiological risks, and this has several implications. It is clear that there is no single “risk rationale” to dealing with risks, and there is no inherent social contradiction if the management of risk is not approached everywhere in a comparable or “equal” fashion, particularly in terms of stakeholder concerns and resource allocations. At the same time, aspects important at the international level can be subsidiary to those at the national level, which can in turn be subsidiary to local aspects. Thus, for example, local issues and concerns play a significant role in the siting of new installations, or in discussion of operational emissions from existing facilities, and discussions concerning different sites can result in different numerical criteria and practical solutions.

Further, environmentalism has continued to grow, to the point where increasingly, and at many levels, there is a link between good public health and a healthy environment. Much of the public demand for a clean environment is thus formulated on the basis of “quality of life” and “well being”. These notions, both as social values and as scientific facts, are central to many of today’s decisions and decision-making processes.

Finally, there is a growing view that radiological protection has for some time been somewhat independent, but should rather be viewed within the broader sphere of public health. In this context, the assessment and management of radiological risks are, as with environmental protection, reformulated as being viewed together with many other risks and issues to be addressed to achieve good public health in a balanced fashion.

Experience and lessons learnt

In addition to the scientific and social evolution that have been mentioned above, the implementation of radiological protection over the past 15 years has resulted in much experience and in many “practical” lessons learnt. In particular, it is increasingly clear that some level of control can, and should, be maintained over all sources and exposure situations. A corollary to this is that the management of risks, while in general fitting within a broad, generic framework, will be largely driven by the specific circumstances under consideration.

Societal desire for an increasingly participatory democracy is exerting pressure on the current system to evolve, in particular in the direction that was

first articulated by the ICRP Chair in his 1999 paper on “controllable dose”*. Specifically, individuals feel that all risks are manageable at some level, wish to participate in the management of their own risks, and feel capable of doing so. As an example of where experience has shown the current approach to be questioned, a central aspect of the 1990 ICRP recommendations was the artificial distinction made between “practices” and “intervention”. This was noted as posing practical problems even in the 1994 CRPPH Collective Opinion:

There are problems with public understanding and acceptance of the rationale suggesting that dose limits apply in the case of practices but not in the case of interventions to reduce existing exposures, such as exposure from contamination resulting from past practices or past emergency situations. There is, therefore, a need to do more to improve public understanding of the differences in approaches to control doses from practices and intervention situations, both from a conceptual and practical standpoint.

The 1990 ICRP doctrine considered that putting any type of “upper bound” (e.g. limits or constraints) on exposures resulting from accidents or “discovered” situations was appropriate because such circumstances are by their very nature unpredictable. Further, it considered that below some pre-defined intervention level it was most likely not justified to act at all. Emerging societal values suggest that the current focus of concern lies elsewhere. Increasingly since 1994, experience shows that there is no value in maintaining separate approaches for Practices and Interventions. In general, the response to what were called intervention situations is now seen as more controllable, and the specific circumstances of the case under consideration are essential to decision making in such situations. The inherent ability to control actions to reduce exposures brings the focus more towards the process of optimisation of protection, with the caveat that exposures should as best possible be maintained below some “reasonably chosen” upper bound (i.e. to prevent deterministic effects, to reflect industry good practice, to recognise the magnitude of natural exposures and the efforts necessary to affect change, to ensure equity in the distribution of exposures, etc.).

This shift in focus can be seen in decision makers’ reactions to the application of emergency countermeasures in nuclear emergency exercises. The NEA INEX Exercises have clearly shown that intervention levels, while used effectively as planning tools for estimating the needed magnitude of response resources, are generally not considered when deciding whether or not to implement a protective action. Rather, protection decisions are focused on optimisation of protection to achieve residual doses that are ALARA.

* Roger Clarke, “Control of low-level radiation exposure: time for a change?” 1999 *J. Radiol. Prot.* 19 107-115.

These concerns are reflected in ICRP recommendations currently under development, which suggest constrained optimisation in all types of situations (planned, emergency and existing), and do not impose lower-bounds on optimisation below which actions are not justified.

In addition to the notion of controllability, the importance of case-specific circumstances has led some decisions away from the strict use of “universal” and international criteria often found in the current literature. The focus of concern has turned to case-specific optimisation. This is very clearly seen in situations involving the release of radioactive materials from regulatory controls. Here again, the doctrine described in ICRP publication 60 has been interpreted to suggest that generic values can be identified below which regulatory actions should not be warranted, and as such exposures should be exempted. While generic figures, among which the value of 10 μSv is often cited, have been of use in decision making under some circumstances, generic application for the releases of materials (solid, liquid or gaseous) containing radioactivity from regulatory controls has not always been accepted. Rather, for the release of sites after cleanup, or the release of materials for disposal, recycling or reuse, or the emission of gaseous or liquid effluents, local, site-specific discussions to identify the optimum protection solution, perhaps using standardised values as a guideline or starting point, are increasingly the norm.

A question intimately tied to this, and that awaits an answer, concerns the definition of the “scope” of the radiological protection system and its regulatory implementation. The current approach, defines exposure situations that can be “excluded” from the scope of the system of radiological protection based on their amenability to control, and also defines “exemption” levels below which some specific regulatory requirements may be withdrawn. National regulatory authorities, who are generally required to address all radiological concerns that are known or brought to their attention within their legal mandates, will have to consider the best way to implement radiological protection principles. The NEA report on the *Process of Regulatory Authorisation* (NEA, 2006) discusses this issue at length, and suggests that the concepts of exclusion and exemption may not be fundamentally necessary for the effective regulation of radiological protection.

Historical perspective

The principles of radiological protection were originally developed by radiologists and radiation researchers to protect themselves from the harmful effects of radiation, which emerged early in the 20th century. Over time, and as the uses of radiation and radiation-producing devices evolved, these principles matured to reflect the need to protect patients, workers, and eventually the

public. Now, expansion to the radiological protection of the environment is being considered. Throughout this development, which has lasted almost 100 years, radiological protection has pragmatically adjusted to appropriately address new and arising issues, broadly basing its direction on consideration of equity (the limitation principle), precaution in the face of uncertainty (through the LNT construction and its application in optimisation), and responsibility (the justification principle).

The ICRP system of radiological protection has evolved based on periodic publication of “general recommendations”, which have historically been followed by one or more additional recommendations, often addressing specific issues that have arisen. Through this process, the “smooth” and “harmonious” system described by the general recommendations becomes “lumpy” as the general recommendations are interpreted, and new approaches are added to address issues arising. As such, the next “general recommendation” attempts to reconcile additions and new approaches once more into a single, smooth and harmonious new system of radiological protection. This has been the case through several iterations, beginning with the first truly general recommendations, Publication 1, in 1959, and with new general recommendations in Publication 9 (1966), in Publication 26 (1977), and Publication 60 (1990). Issues and new circumstances that have provoked the need to re-assess the general recommendations have included scientific advances, such as new assessment of dosimetry for the Hiroshima-Nagasaki bomb victims, new arising circumstances, such as the Chernobyl accident, or the realisation of the large and pervasive nature of radon exposure, and social evolution, such as the increasing role of stakeholders in decision-making processes.

In addition to these lessons, several sectors have seen growth in the past years, or will likely see growth in the coming years, posing additional needs and challenges to radiological protection in that policy and regulation generally lag somewhat behind quickly expanding applications. Nuclear installation decommissioning has become a fully industrialised activity, and will continue to grow in terms of the number of facilities being decommissioned. The NEA programme in this domain has worked for some time to facilitate the exchange of experience, and the maintenance of radiological protection safety culture. In a completely separate area, medical diagnostic and therapeutic techniques are rapidly advancing and changing, and related exposures, both of patients and of medical personnel, are growing very quickly. Both of these growth areas require attention from the radiation protection community, particularly in terms of assuring that effective and functioning safety cultures are instilled in all those involved. In many circumstances, experience has shown that it is most effective to address these areas in a holistic fashion, with broad stakeholder input, to appropriately account for the inherent complexity of the situation.

Key historical mile-markers

Early 20th Century	Focused on deterministic effects, developed limits.
	Studied genetic effects.
	ICRU created in 1924.
	ICRP created in 1928.
	Quantitative measurement of radiation.
Before and during WWII	Shift of focus to radiation biology.
	Early criteria for exposure limitation.
	ALAP.
	Manhattan Project.
	Hiroshima/Nagasaki.
During the 1950s	Leading role of NCRP.
	Atoms for Peace Conferences in 1955 and 1958.
	RERF, stochastic effects from Hiroshima/Nagasaki cohorts.
	ICRP General Recommendations in 1950, 1954.
	UNSCEAR created to scientifically address political (proliferation, weapons testing) issues.
	IAEA created in 1957.
	NEA CRPPH created in 1957.
First ICRP recommendations published in 1958.	
From 1960 to 1990	ICRP General Recommendations in 1964 (Publication 6), 1966 (Publication 9), 1977 (Publication 26).
	IRPA created in 1966.
	Emergence of the ALARA principle was first described in Publication 26 (1977).
	Broad stability of the system.
	Chernobyl.
	Emergency preparedness and management issues.
	Development of new dosimetry, new risk coefficients.
During the 1990s	Interpretation and Implementation of Publication 60 Principles.
	<ul style="list-style-type: none"> • Justification, Optimisation, Limitation. • Practice/Intervention. • Protection against Radon.
	New radiobiology, radioecology.
	Rio Declaration on Environment and Development 1992, with the precautionary principle and sustainable development as key features.
2000 and beyond	Terrorism and protection of sources.
	Protection of the environment.
	Development of the next ICRP Recommendation.
	Focus on optimisation in all exposure situations.
	Stakeholder Involvement.

Recent trends

Until the issuing of ICRP Publication 60 and somewhat thereafter, it can be asserted that the radiological protection community viewed its role as one of clarification of scientific facts and evidence into radiological protection principles, standards and regulations. As has been noted, the growing role of stakeholder involvement and participatory risk governance have altered this previous reality of radiation protection being solely seen as “good science”, towards the emerging view of radiation protection as a social judgement informed by good scientific knowledge. The series of Villigen workshops (1998, 2001 and 2003) that were organised by the CRPPH have highlighted the premise that the radiological protection community should primarily focus on “integrating radiation protection into social decisions, not integrating social decisions into radiation protection”, and have provided concrete lessons and experience in this area.

Stakeholder involvement in risk assessment and management is increasingly common in many types of decisional processes. This shift has had several concrete and profound effects on the currently emerging system of radiological protection:

- There seems to be a shift towards greater focus on exposures that are controllable, and thus towards protection at the source.
- There seems to be more concentration on the use of source-related dose constraints, with optimisation below the constraint, as the primary approach to implementing protection. This approach is proposed for all situations that are planned, emergency, and existing situations.
- Decisions on Justification and Optimisation are now basically seen as social judgements informed by scientific, radiological protection information, and can be significantly affected by the specific circumstances under consideration.
- The rationale for the selection of numerical values for various radiological protection criteria (e.g. dose limits, dose constraints) has evolved since 1990, and increasingly includes such considerations as:
 - natural background radiation levels as context;
 - assessment of risk;
 - consideration of exposure distribution (equity).
- It has been broadly accepted that natural and artificial radiation must be addressed within a single framework of radiological protection.
- Environmental protection is increasingly seen as a key element in many decisional processes.

Taken as a whole, these pressures suggest that future consideration of radiological risk assessment and management will be influenced by stakeholder involvement processes, and that prevailing circumstances will be strongly taken into account, perhaps leading to specific, local solutions. The balance between internationally harmonised approaches and local specificity must therefore be a central issue in the future development of radiological protection principles.

Future development of RP principles

The ICRP has considerably changed its approach to the development of new principles and recommendations, influenced strongly by social evolution towards stakeholder involvement. Until the 1999 ICRP open paper on controllable dose,* recommendation documents were developed in a rather closed, expert-group fashion. With the opening of the development process to broad dialogue and comment, which began with the consultation of radiological protection professionals in the context of the IRPA-10 international congress in Hiroshima in 2000, the process has significantly changed in what will most likely be an irreversible fashion. Draft materials are developed by the ICRP, but these are then broadly discussed with various organisations and stakeholder groups, comments are received, and new recommendations are developed taking these into account.

It should be recalled that the recommendations of the ICRP have always required much interpretation in order to transform them into international standards and national regulations. Part of the discussion of draft recommendations, which is embodied in the new process of recommendation development, has clearly taken this interpretation a step up-stream, resulting in final ICRP recommendations that are more easily translated into practical application in standards and regulations. Although the role of the ICRP will remain central to the development of future recommendations, it is likely that other organisations will increasingly bring relevant input to this process.

This broadening of input highlights the roles of organisations other than the ICRP in the development, interpretation and implementation of radiological protection principles. Although many organisations have long been essential in the development of scientifically sound, practically applicable approaches to radiological protection, their roles have not necessarily been sufficiently visible, and their actions have not necessarily been sufficiently co-ordinated. The “new” approach that the ICRP has instigated for the development of its recommendations will surely have an effect on the work of all relevant organisations, e.g. NEA, IAEA, UNSCEAR, WHO/FAO, ILO, EC, and IRPA in the future.

* Roger Clarke, “Control of low-level radiation exposure: time for a change?” 1999 *J. Radiol. Prot.* 19 107-115.

This highlights the opportunity to revisit the roles and responsibilities of all radiological protection organisations in the management of radiological risks. The CRPPH reflected on this during its 64th meeting, in March 2006, where the qualities of the NEA and the Committee were discussed. The Committee is seen by its members as a unique resource, to them and to the radiological protection community at large, having a forward-looking and open-minded approach to emerging and evolving issues, and acting as a laboratory for the development and refinement of ideas.

Understanding the historical perspective of the development of radiological protection principles and recommendations is clearly essential to effectively moving forward with their evolution, interpretation and application. The next sections of this report will elaborate on the specific areas where various influences may result in challenges in the years to come.

KEY ISSUES FOR THE FUTURE OF RADIOLOGICAL PROTECTION APPLICATION

The evolution in radiological protection science, experience with implementing the radiological protection, and social evolution suggest that there will be a growing need to more explicitly consider the balance between internationally-agreed, harmonised approaches to radiological protection, and locally-driven, case-specific solutions. In general, processes will be needed for achieving the balance required to take issues forward with regard to both public and worker exposures. The views of the CRPPH on these issues will be discussed in this section.

Four types of situations have been identified as in need of particular attention in the context of current RP science, experience and social evolution: the release of contaminated areas and materials; decommissioning; medical exposures; and radiological terrorist actions. These areas are presented here in no particular order of priority.

Finally, an ongoing and overarching concern is the need to transfer our inheritance of knowledge to future generations of radiological protection professionals. This will briefly be discussed.

Balancing local, national and international needs

In addressing radiological protection situations it is sometimes necessary to balance the needs of the “local stakeholders”, i.e. those who are or would be affected by the radiological situation at hand, and the national and international constraints and agreements that are necessary and/or desirable to maintain broadly coherent approaches to radiological protection, and the international flow of people, goods and services. The issues at hand can be characterised as the willingness on one side to apply a precautionary approach (focusing on the local, case-specific circumstances), and on the other side to adopt a holistic approach to radiological risk management, focusing on the broader, international view.

While such balancing has been part of decision-making processes for some time, the increased focus on stakeholder involvement over the past years has

had, and will continue to have an effect on the aspects that are considered and approaches that are taken to developing radiological protection decisions. These two, sometimes contradictory concepts are discussed here.

Holistic approaches to risk management

Description of the issue

The technological advances of the last century or so have greatly influenced the evolution of modern lifestyle. While many new “benefits” have emerged, so have many new “risks”. Because of the inherent complexity of modern life (e.g. scientific, structural, governance, etc.) it is generally very difficult, if not impossible, to balance the management of risks in a global fashion. In the face of this difficulty there are many examples, in both the national and international contexts, of the need for global balancing of risk management, particularly in terms of resource management.

For example, from an operator’s point of view, in an industrial facility workers may be subject to many different risks: radiation exposure, chemical exposure, industrial accidents, etc. There is a clear need to manage all these risks at the same time, but it is often difficult to balance, based on multi-risk assessment, the allocation of resources to “appropriately” address these risks.

From a regulator’s point of view, there are many types of risk (e.g. radiological, chemical, industrial) that exist across many different industries. For example, radiological risks are found in the nuclear industry, in the medical industry, in the pharmaceutical industry, in manufacturing, and in many other areas. It would seem logical to have a common approach to addressing the same risk across all industries. While this is possible in certain situations, case-specific differences in risk management approaches can be seen in numerous instances. The different ways in which naturally occurring radioactive materials (NORM) and artificially-generated radioactive materials are addressed materials is just one example. Again, a broad, unified approach to risk management is difficult to achieve.

From the broad stakeholder viewpoint, there are many situations where risks are transferred from one group to another through various mechanisms. Some sort of mechanism for judging the balancing of such risks would be of great use. For example, in making choices for the management and disposal of long-lived hazardous wastes (nuclear or chemical) risks will be inevitably transferred from the current generation to future generations. Even within the same generation, risks are commonly transferred, for example when identifying and implementing safety improvements, risks are transferred from the public to

workers. In attempting to manage risks in a broad fashion, these and other types of risk transfers need to be taken into account.

Still more broadly, from the international perspective, another dimension to the holistic approach to risk management is highlighted by the global scale of modern life. People, goods and services routinely transit national boundaries. As a result, there is a need for the international harmonisation of certain norms and regulations regarding radiological risks and these global transfers.

These aspects of a holistic approach to radiological risk management are difficult to achieve even individually, let alone collectively.

The effects of change

In spite of these difficulties, pressure and trends are towards taking a broad view of radiological risks among all other relevant risks, and in combination with other risks. Yet as resource allocation and other pressures push in this direction, the evolutionary changes that have been previously discussed, as well as the inherent complexities described in this section, have added to the difficulty of defining and applying a holistic approach to radiological risk management.

Scientifically, our understanding of any particular risk is inevitably accompanied with some degree of uncertainty. In trying to address multiple risks simultaneously, another dimension of uncertainty is added, significantly complicating any comparative assessment. The assessment of health risks posed by toxic agents in food and water is an example of the complexity that issues can have. Different disciplines have tended to work in isolation, and may have different paradigms and approaches (NEA, 2000a). Balancing of different types of risk, which may not be easily compared scientifically, is difficult, but the need to do this may be growing (e.g. safety of food, protection of the environment).

While it is clear that “science” will advance and better understand risks, it is a significant challenge to guide scientific advances through a common social understanding of the “objective” of “safety” – for example, what do we want to achieve with “radiological protection”, with “environmental protection”, with “food safety”? The development of broad, international agreements is increasingly difficult, particularly in that there is an expansion in the types and backgrounds of relevant and interested stakeholders at both the national and international level. As such, the focus of discussions aiming to reach internationally harmonised approaches has somewhat shifted from the technical aspects of risks coming from the global movement of people, goods and services, to the more social aspects of such risks.

Experience over the past years illustrates these difficulties, for example in the areas of harmonising national approaches to radiological emergency response, or to applying harmonised national and international approaches to trade in slightly contaminated goods and materials.

All of these issues pose conceptual, social and scientific challenges to the development of any over-arching, holistic approach to the identification and management of risks.

Future direction/what questions remain?

In working to achieve international harmonisation of radiological risk management approaches, traditionally the focus has been on reaching agreement in the context of the risks involved. However, reducing the argument to a discussion of risk tends to be too limiting to solve most complex issues. While the direct risk comparisons and risk rankings that are often used are inherently simple and can reduce complexity, they can not alone resolve complex radiological protection issues where there is a significant component of social judgement involved, or when the scientific inter-comparability of the risks under discussion is difficult.

As such there is a need to reach beyond radiological protection science to resolve these issues. For such an effort, it is clear that the relevant stakeholders will need to be centrally involved. One way to approach such discussions is to search for common values among the relevant stakeholders (NEA, 2004c), addressing risks as well as benefits. This would serve the double purpose. First, it would move discussions towards the identification and clear definition of a common objective, e.g. what do we want to achieve with radiological protection, or more broadly with public and worker health and safety and with environmental protection. Second, it would provide guidance for any scientific research needed to advance safety goals.

This suggests the need to begin with a broad view, for example looking at radiological protection needs from the context of sustainable development, of public health concerns, or of improving the quality of life of the stakeholders affected by the situation under discussion. To achieve this, radiation protection science must become increasingly involved with other social and scientific views, policies and approaches. Finding approaches and commonalities to bring these different viewpoints closer with regard to risks and protection objectives will be one of the keys to success.

The precautionary principle and radiological protection

Description of the issue

The system of radiological protection has been built to provide a framework to address radiological protection questions, and to develop protection actions in the face of scientific uncertainty with regard to the exact nature and magnitude of radiological risks, particularly at low levels of exposure to radiation. Through the assumption of some risk even at low levels (the “LNT” construction) and the consequent approach to optimisation (controlling doses “ALARA”), the current system of radiological protection can be argued to have taken a precautionary stance since its early development period in the 1950s. In the meantime, the world at large has embodied the need to act with some prudence in what is known as the Precautionary Principle.

In the light of the current state and research directions of radiological-protection science, of experience over the past 15 years or so in implementing the system of radiological protection, and of current social approaches to risk assessment and management, there is a need to revisit how the widespread commitment to the precautionary principle does, and may in the future, affect radiological protection situations.

The effects of change

Although there are different views on what the precautionary principle means in practice, where it has been written in international agreements or national statutes, the precautionary principle generally states that a prudent approach should be taken in the face of uncertainty with regard to risk, and that scientific uncertainty should not on its own be used as reason not to act. This embodies both the notions of scientific knowledge/uncertainty and subjective judgement.

From a scientific standpoint, uncertainty with regard to the detrimental effects of ionising radiation seems to be increasing rather than decreasing. Although the effects of radiation are amongst the most studied of all detrimental and carcinogenic agents, the work of the CRPPH Expert Group on the Implications of Radiological Protection Science (NEA, 2006b) has highlighted that many possible scientific developments could challenge the “simplified, one-size-fits-all” approach to radiological risk assessment and management.

The precautionary principle has many definitions, and is often applied in the context of environmental protection. The following are examples of definitions that have been used in national and international documents.

Communication of the European Commission COM(2000)1

“Where action is deemed necessary, measures should be proportionate to the chosen level of protection, non-discriminatory in their application and consistent with similar measures already taken. They should also be based on an examination of the potential benefits and costs of action or lack of action and subject to review in the light of new scientific data and should thus be maintained as long as the scientific data remain incomplete, imprecise or inconclusive and as long as the risk is considered too high to be imposed on society.”

Rio Declaration on Environment and Development 1992

Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Canadian Environmental Protection Act 1999

Where there are threats of serious or irreversible damage, lack of full scientific certainty shall not be used as a reason for postponing cost-effective measures to prevent environmental degradation.

Australian Environment Protection and Biodiversity Conservation Act 1999

lack of full scientific certainty should not be used as a reason for postponing a measure to prevent degradation of the environment where there are threats of serious or irreversible environmental damage.

French Environment Code Article L110-1 (Loi n° 2002-276 du 27 février 2002 art. 132 Journal Officiel du 28 février 2002)

(...) the absence of certainty, based on current scientific and technical knowledge, must not delay the adoption of effective and proportionate measures aiming to prevent a risk of serious and irreversible damage to the environment at an economically acceptable cost.

From the standpoint of subjective judgement, the precautionary principle could be said to be applied in radiological protection situations through the use of the basic principles of limitation, optimisation and justification. These have, in the past, been largely based on quantitative, decision-aiding techniques, but are increasingly based on subjective judgements that are informed by a scientific characterisation of the situation at hand.

Both the scientific and social directions of change described here suggest that there will be an increasing pressure for radiological protection solutions to be finely tuned to address the specific case at hand, informed by the most appropriate and specific scientific knowledge that is available at the time. This, in turn means that the use of generic, global, homogeneous approaches across many specific cases will come under increasing pressure as being ill-adapted.

Clearly not all situations will present complex or controversial aspects, and thus most will be addressed in a straight-forward fashion by a limited group of interested/relevant stakeholders (e.g. simply the regulator and the operator). However some situations will be more challenging. The release of radioactive materials or sites from institutional control, the siting of new nuclear installations, the rehabilitation of areas contaminated by a nuclear or radiological emergency situation, or questions regarding ongoing, operational effluent releases are but a few examples of situations that exist today, that can be scientifically and socially complex, perhaps in some cases requiring a very strict application of a precautionary approach or possibly even, in some cases, requiring a more relaxed approach as trade-offs are made.

Future direction/what questions remain?

The interpretation of what is “reasonable” in terms of radiological protection is at the heart of the application of the precautionary principle. This has both scientific and socially judgemental aspects. To maintain a precautionary approach, set against a widespread uptake of the precautionary principle, the field of radiological protection will need to keep abreast of, and adjust to, changes in both science and society.

To address challenges to the use of a single, “standard model” for radiological risk assessment and management based on the use of LNT, and of the Sievert as a surrogate for harm, there is a need to continue scientific research so as to reduce and better define scientific uncertainties. Further research may increase support for the current approach, or alternatively, may call it increasingly into question. As such, there may come a time when it will be necessary to decide whether it is appropriate to make significant changes. In either case, there will be a need to balance radiological protection policy needs

with scientific knowledge in the broader context of maintaining a precautionary attitude, such that both policy makers and scientists are aware of each others' concerns, and such that policy needs appropriately drive scientific research.

Clearly, to achieve these goals, there will be a need to continue research, to build better bridges between the policy, regulatory, application and scientific communities, and to assure a great a transparency of information and decision making as possible.

Applying radiological protection principles to public and worker protection

The need to balance the local, national and international aspects of decisions, maintaining an appropriately precautionary approach, will be manifest in discussion regarding the protection of the public and of workers. Because of the inherently different nature of the stakeholders in these two protection situations, the structural aspects that are used to achieve the necessary balances to move forward will be different. In the case of public protection, an approach to achieving the appropriate balance could focus on improving the transparency of decisions and on building and maintaining effective citizen vigilance. In the case of worker protection, the appropriate balance could be achieved through a vibrant, living safety culture.

Transparency in decision making/citizen vigilance

Description of the issue

Decision-framing and decision-making processes have evolved significantly over the past years. Beginning with the social upheavals of the 1960s, the barriers that once surrounded risk assessment and management decisions and decision-making processes have been increasingly disappearing. The days when public officials and technical bureaucrats could, to the best of their judgement, make public-protection decisions in isolation and on behalf of the public are gone. Today, many groups and individuals are interested in being involved, at various levels of participatory democracy, in discussions and decisions affecting public health and environmental protection issues.

This increasing interest in decision making has been paralleled by, and is perhaps at least in part driven by, a decline in belief in of government expertise. The technological promises of post World War-II advances have often not lived up to initial claims, breeding some scepticism of science and public institutions. With this has come the increasing realisation that science is only part of "the truth" with respect to judgemental decisions affecting such things as "safety", "security" and "the environment". Environmentalism has also continued to

grow, to the point where increasingly, and at many levels, there is a link between good public health and a healthy environment. Much of the public demand for a clean environment is thus formulated on the basis of “quality of life” and “well being”. These notions, both of social values and of scientific facts, are central to many of today’s decisions and decision-making processes.

These evolutions have resulted in the emergence of social values as being, in many cases, significantly more influential than scientific fact with respect to decisions. Modern communication technology and the availability of information have contributed to this shift by making it possible for individuals and organised stakeholder groups to much more independently acquire information regarding relevant risks.

Similarly, there is a growing view that while radiological protection has for some time been somewhat independent, it could better serve the public good if it were viewed within a broader context, for example that of public health. In this vision, the assessment and management of radiological risks are, as with environmental protection, reformulated as being together with many other risks and issues to be addressed to achieve good public health in a balanced fashion.

The effects of change

The effects of these shifts on approaches to risk identification and management can be seen increasingly clearly.

For example, it is evident that in many situations government experts can not alone identify the key issues of concern to stakeholders. With the increasing democratisation of information, and the rising prominence of social judgement in decisional processes, it is often the case that a multitude of different viewpoints must be addressed in any complex radiological risk situation. Here, the role of the expert has become one of contextualising case-specific risks with respect to the broader perspective, and with respect to stakeholders’ views, rather than simply calculating doses and informing on results and decisions. This may often pose challenges to the management of the differences between local perception of benefits and risks, and broader national level goals, agreements and regulations.

These changes can manifest themselves in pressures for increased transparency, increased participatory governance, and increased access to independent public expertise. In many instances, these pressures are well in advance of legislative, regulatory and institutional/structural developments. As with many modern issues, these pressures are augmented by the speed of modern communications and information availability.

The fluidity of modern communications has also increased the availability of “second opinions” with regard to scientific input to decision making processes. Many stakeholders turn to experts beyond those provided through governmental institutions as sources of credible scientific assessment of radiological risk situations and management options. Stakeholders may also wish to independently monitor agreements, for example through the establishment of mechanisms for periodic and/or ongoing environmental radiological measurements, to independently assure compliance or to signal worrying trends. Clearly such evolution will increasingly reinforce the role of public participation in the management of the radiation exposures affecting them. It will also favour an appropriate balance between international and national level harmonised radiological protection requirements, and local, case-specific concerns.

Future direction/what questions remain?

While the central importance of stakeholder involvement in addressing some risk situations is now widely accepted, it will be important to optimise structures and processes to facilitate appropriate participation, to enhance transparency of information and decision making, and to work towards convergence when conflicting views arise. Such an optimisation has many aspects, some of which will be generic, and some of which will be contextual.

In a general sense, there may be a need to change policies and regulations at the national and international levels. For example, many countries have in place legislative mandates for transparency of information and decision-making processes. The Aarhus Convention 1998 is an example of a regional agreement, in this case centred on Europe, which provides requirements concerning access to information, public participation and access to justice over environmental matters. However, even where such instruments exist, there may a need for specific legislative or regulatory refinements for direct application to information and public participation in the area of radiological risk management. In this same context, the structural aspects of governmental radiological regulation and expert organisations may need to be revisited, and perhaps modified, in order to best facilitate the implementation of stakeholder involvement in decision framing and decision making processes related to radiological protection.

There will certainly be a need to consider the types of tools and expertise that are necessary to resolve such situations. For example, with the shift in emphasis towards judgemental decisions informed by science, there will be less a need for classic, decision-aiding techniques than for support of new processes and tools to inform and facilitate dialogues, debates and deliberations. In this context, there will be a need to involve more than one type of expert in order to

perform a truly pluralistic assessment This will also most likely require some optimisation of the types of personnel available from governmental expert institutes, and for some rethinking of the training that radiological protection experts receive at the university level and through their continuing education efforts. Some evolution of “mindset” may also be needed in experts.

In working to balance broad and perhaps diverging concerns, the Villigen workshop series has clearly demonstrated the value of sharing of international experience. Further discussions of “generic” approaches, lessons and experience might assist countries in refining their own, general and situation-specific approaches to involving stakeholders in decisional processes. These can contribute to the development of “common approaches” in some situations, such as multi-national discharges into a common water body (e.g. discharges to oceans, seas, or rivers), or for determining ways to discuss several different risks at the same time (e.g. food safety) to achieve coherence of values across several risks.

At the same time, it is important to recognise the difficulties with the implementation of stakeholder involvement. For example, stakeholder involvement seems to be most “manageable” in “local” situations. Large-scale regional, national or international situations may require that new approaches be developed, although it is clear that international sharing of actual experience, at a detailed level can be useful.

Maintenance of radiation protection and safety culture in the workplace

Description of the issue

Over the last decade, there has been a rapid expansion in the use of irradiating apparatus and radioactive materials in many fields, particularly in medicine. This expansion is not only in terms of an increase in the number of industrial and medical facilities using ionising radiation, but also in terms of the number of new procedures and new applications, particularly in medicine, such as interventional radiology and IMRT (intensity modulated radiation therapy). This expansion has increased the demand for staff skilled in radiation protection techniques. It has also increased the need for training in radiation protection for professional groups that heretofore would not have used ionising radiation e.g. cardiologists. The pressure to implement new techniques has resulted, in some instances, in a low-priority being assigned to radiation protection issues. The proliferation of “one-man” operations using ionising radiation, such as dentists and chiropractors, present particular challenges. There is an increasing recognition of the need to maintain the professional/technical infrastructure for radiation protection in order to prevent a major gap developing between the needs of industry and medicine and the capabilities of the infrastructure.

In the nuclear industry, the history has been somewhat different with different forces at play. With some notable exceptions, following the accidents at Three Mile Island and Chernobyl, many countries decided not to proceed with their new reactor programmes and a number commenced a gradual shutting down of existing facilities. This “decline” in the nuclear industry meant that the supply of new professionals entering the field was curtailed. While it is well recognised that advances in technology during the last decades have improved the engineered safety of reactors, it is still the case that many of the more serious nuclear installation incidents and accidents have resulted to a greater or lesser extent from operator error and the lack of a well-developed safety culture within the plant, e.g. Tokai Mura. Accidents of this type impact greatly on public confidence in the nuclear industry.

In addition to the issues associated with the maintenance of radiation protection as a profession, it is now acknowledged that the system of protection itself, while effective, is complex. In particular, the implementation of the concept of optimisation (ALARA) requires in many cases, much more than simply good radiation protection common sense. Against a background of constant pressure to increase productivity while at the same time reducing costs, the goal of optimisation can sometimes be set aside and a poor safety culture may result in levels of exposures to workers which are far from as low as reasonably achievable, given the prevailing circumstances.

The effects of change

In the past, the approach to an increase in the requirement for radiation protection services was in general to increase the number of specialists in radiation protection. Nowadays, the approach is rather to integrate radiation protection into the general framework for risk management in the workplace. While there is still a need for radiation protection specialists, a more integrated approach results in a variety of professionals with generalist knowledge of radiation protection.

Following a number of high-profile accidents in the nuclear industry, there has been a greater recognition of the importance of safety culture. Regulators, who in the past would have been mainly focused on plant design and operation, have now developed indicators to help them evaluate this “softer” but crucially important characteristic of a facility. In doing this, they have drawn from the experience of risk management techniques in other industries. There is an increasing consciousness of the need for a “holistic” approach to operation and regulation and for “whole-system” thinking which strives to understand issues from a perspective broad enough to see the larger context from which the issues are arising.

Future direction/what questions remain?

The aspects of interest in this area can be characterised in terms of their timeframe: there is a need to “look back” so that past experience is appropriately assessed and available; there is a need to “teach today’s experts” so that safety culture is transmitted to today’s workers; and there is the need to “look forward” to use experience to fix the expectations for future work.

The science of radiation protection has developed over many decades and during that time many important lessons have been learned. While the principle focus will always be on moving forward and progressing, it is crucial that the lessons learned in the past are not forgotten and that a means of maintaining a strong collective memory is developed. This is particularly important when considering approaches to infrequent and irregular events, such as particular types of accidents.

If radiation protection as a discipline is to be adequately maintained, it is important that training in radiation protection is continuously updated and kept relevant to those who need to know it. This requires the sharing of experience in effective training methodologies, both within the field of radiation protection and in the broader context of training in the workplace. One of the underlying causes of poor safety culture is inadequate or inappropriate communication of the risks involved. It is a continual challenge to develop effective means of communicating the risks associated with ionising radiation to a very broad spectrum of workers with very different backgrounds. One of the key communication channels is that between radiation protection professionals and managers who have the ultimate responsibility for maintaining the safety culture.

There is a need to continue to consider how radiation protection can be better integrated into standard work practices and the overall risk management system in the workplace. Improved integration and a broader perspective can lead to better solutions – “two heads are better than one”. In this context, the experience that has been gained must form the basis for optimisation of future endeavours having a radiological protection component. Through the application of experience and state-of-the-art technology, and the maintenance of a strong safety culture future nuclear installations should achieve better radiological protection results than today, and such criteria should be considered in the design of new installations.

Many of these challenges will appear in new ways in the future. For example, the medical and industrial use of radiation is expanding, and building and maintaining a safety culture in these environments will be necessary. Possible new growth in the nuclear industry will require the transfer and

maintenance of experience and experience exchange processes (e.g. ISOE). New nuclear reactors (e.g. Generation IV) will need to base their design and operational objectives on current “state-of-the-art” technology and processes. All of these challenges must be addressed, at least partially, through a reliance on strong safety culture in the workplace.

Application of radiological protection principles in specific contexts

In addition to the dimensions that are expressed by considering public and worker radiological protection, there are several contexts in which it seems clear that radiological protection application will require specific consideration increasingly in the future.

The legacy of contaminated areas and materials

Description of the issue

Approaches and criteria for managing radioactive materials released to or discovered in the environment have long been discussed within the radiological protection community. Although there are many such situations that require radiological protection decisions, it is possible to group them into three broad categories: 1) areas that have been contaminated by ongoing, controlled operational releases; 2) slightly contaminated materials that have been released from regulatory controls; and 3) industrial and nuclear sites from past activities. The decommissioning of nuclear installations, belonging in this last category, deserves particular attention because there is growing number of such facilities around the world.

There are many installations that are currently releasing, under regulatory controls, liquid and gaseous radioactive effluents into the environment. These releases may be re-evaluated in the face of changing circumstances. For example, many existing facilities are being upgraded, and/or are having their design lifetimes extended. There is also increasing discussion of building new nuclear power plants and related support installations (e.g. fuel fabrication, enrichment, reprocessing). These new facilities would also, most likely, be licensed to release some level of radioactive effluent to the environment. While all of these facilities are under regulatory control, their releases are causing, or would cause, some accumulation of the longer-lived radionuclides in the environment.

Although there exist, for the moment, few foodstuffs or commodities that are released from radiological regulatory controls to the market, there continues to be much discussion of how such materials would be handled should a significant contamination event occur (e.g. a large-scale accident at a nuclear installation, or to a lesser extent a deliberate malevolent act, etc.).

Although these three types of situations present significantly different challenges, the commonality they share is that they have generally been approached as intervention situations as defined in the ICRP Publication 60 general recommendations. As such, and even though many of these situations include significant aspects of chronic exposures, the framework for management decisions has been different than that which Publication 60 calls controlled practices. The fact that this management rationale and the target levels of protection are significantly different than what the public has experienced under controlled practices, and the fact that many situations, particularly those involving natural radioactivity, fall into a “grey area” between a Practice and an Intervention have further clouded the issues. In this context, the existing radiological protection system has failed to explain and support properly its rationale to apply different standards of protection in different situations, with less restrictive criteria being applicable in cases of real presence of radioactivity in the accessible environment.

The effects of change

The key driving force for change in decision making and management of such situations is the increasing interest shown by stakeholders to actively participate in decision making. Many situations are today seen as much more “controllable”, within the general context of public and environmental health and welfare, than they were previously and this has a strong influence on attitudes towards what is acceptable and what is not.

The current approach to the management of such situations tends to focus on the scientific and technical aspects, using risk, in the form of dose, as the ultimate indicator and the notion of a pre-established, universal value below which concern is neither justified nor warranted, as criteria for action. Particularly when large groups of people are involved, as can be the case in legacy situations, such an approach is not normally able to cope appropriately with the complexity of the problem. Situations when whole regions are affected are a particular example of this, where societies may well be more directly concerned with restrictions in life and progress due to land contamination than with radiation dose to individuals.

It must also be recognised that situations, values, attitudes, and available resources of societies change with time, clearly affecting views of radiological protection. Past experience suggests that the level of dose people actually receive in contaminated environments plays a key role in deciding whether to take action or not and that, most probably, current requirements will become more stringent in the future. Further, it should be foreseen that some present practices may not be continued due to changes or developments of industrial,

medical or other fields of society and present sites of those practices may need to be released for other, perhaps non-radiological uses. The challenge is how to prepare in a timely and responsive manner for the management of the existing legacies as well as of future legacies from today's activities.

Future direction/what questions remain?

In all legacy situations, the notion of stakeholder involvement and of pluralism in decision making is increasingly important. Decisions need to be appropriately informed by many sides of an issue, including the scientific, economic, societal, psychological, ethical and political factors that influence decisions. Collectively, these aspects indicate the need for a holistic view of the situation, and for suitable mechanisms to identify all options that are available so as to come to a solution under the prevailing circumstances.

A situation of particular difficulty has been dealing with natural radioactivity. The ubiquitous and "natural" nature of exposures from natural sources have often resulted in significantly different treatment for these sources as compared to the handling of "artificial" radiation sources. This is particularly true for radon, but can also be the case for uranium or thorium often found in building materials (e.g. phosphor-gypsum, bottom-ash from coal burning, etc.). The different approaches to radiological protection against natural and artificial sources have been seen in both a positive light, as the direct result of stakeholder involvement and case-specific solutions, and in a negative light, as a misuse of the system of radiological protection which states that "equal" radiation risks should be treated equally, regardless of their origin.

The challenges presented by these types of legacy situations will ultimately require the balancing of harmonised, international approaches with the case-specific, local considerations emerging from the specific situation being considered. This is also true of the trade in food and commodities, however because these items may well cross international borders, there is an inherent need for some level of international agreement, if not harmonisation of approach.

International trade of food and other commodities call for harmonisation of "acceptable" radionuclide concentrations below which their trade should not be prohibited on radiological safety grounds. International efforts to agree on such international standards have been ongoing for many years, have achieved some limited success, but remain relatively untested in practice. However, these standards may not be accepted by consumers and therefore they may thus become subservient to free-market forces. When "clean" product is readily available, the rejection of "contaminated" product may be an acceptable

solution, however if no clean product is available (e.g. in situations where widespread food contamination occurs in an area where the population depends upon local crops) the choices may be more limited. There exist already some approaches to adapt markets in situations where contaminated commodities are traded, for example, using specific contracts, or having specific product labelling, i.e. leaving the consumer to decide. However, even with a flexible response and market solutions, some level of international agreement on practical values could be very useful, even if only as a reference. Further work in this area is clearly needed to achieve an appropriate balance.

Decommissioning and dismantling of nuclear installations

Description of the issue

Decommissioning refers to the administrative and technical actions taken for termination of licences and release of the sites from regulatory controls of nuclear facilities. These include many governmental sites that have become contaminated by past, in some cases military sites, many mining sites with large piles of mill tailings, and “accident-related” sites such as the Three Mile Island and the Chernobyl reactors. These sites are generally under regulatory control or in the process of cleanup for release from regulatory control for radiological reasons.

Decommissioning actions involve decontamination, dismantling and removal of radioactive materials, waste, components and structures. They are carried out to achieve a progressive and systematic reduction in radiological hazards up to the final point defined in the regulations. To date, many smaller and “one-off” nuclear installations have been successfully decommissioned, and an increasing number of “full-scale” installations have been or are in the process of being decommissioned. It can be said that decommissioning is today a mature industry.

They are many factors that need to be taken into account when defining and developing the strategy and hence the timing of decommissioning approaches. These include such aspects as national policies related to energy, safety and environment; national structures to carry out nuclear activities, including proper allocation of responsibilities to conduct decommissioning; plans to reuse plant and/or site; availability of funding; availability of radioactive waste management capabilities; type of plant and operational history; and stakeholder views.

There is neither a “better” strategy nor a “preferred” option when deciding national approaches. However safety and radiological control over the nuclear installations must be assured whatever decision is taken, this favouring perhaps

dismantling as early as possible after shutdown, even more so in countries with limited national radiological control infrastructures and background. Recent decisions taken in some countries seem to be favouring early decommissioning.

Given the maturity of the decommissioning industry, there are no particular problems or questions that prevent activities from progressing. However, three radiological aspects continue to present challenges to the management of decommissioning projects. The first challenge is managing the very large volumes of wastes from the decommissioning process, which can include up to 100 000 tonnes of contaminated concrete and metal wastes per plant. These will range from being very contaminated to being only very slightly contaminated. Governmental policies and regulations, and industrial practices need to address the management of these materials. The second challenge is the decontamination and release of sites and facilities from radiological regulatory controls. The third challenge can be broadly characterised as the management of change, and involves the long-term maintenance of safety culture so as to assure that decommissioning processes are in fact performed in an optimal fashion. In that decommissioning will include activities that are quite different from activities during the operating life of the installation, some adaptation by regulators, management and staff will be essential.

The effects of change

The evolution of the decommissioning industry and of political and social structures and views are influencing approaches to decommissioning, particularly with respect to the three radiological protection challenges described above. Moreover, decommissioning strategies have received more attention in recent years for different reasons, including the desire to reuse sites, or the need to demonstrate stewardship. As a consequence, early decommissioning is increasingly favoured.

Many international approaches have been developed for the “clearance” of slightly contaminated materials. Radiological criteria have been established for many years, and suggest that the release of materials that cause annual effective doses of 10 μSv or less should be of no concern and should not warrant regulatory controls. From this dose criterion, a series of operational levels, generally in terms of volumetric activity in Becquerel per kilogram (Bq/kg), or surface activity in terms of Becquerel per square meter (Bq/m^2) have been developed for most relevant radionuclides. In general, conservative exposure scenarios have been used. However, in spite of reaching international agreement on such criteria and practical indicators, national-level application of this approach is far from uniform. In that some of these materials, in particular slightly contaminated scrap metal, may cross national borders, some sort of an

international understanding of trade in slightly contaminated materials is necessary. For now, as noted previously in the context of slightly contaminated commodities, consumers and industrial producers seem to be reluctant to the recycling of materials coming from the decommissioning of nuclear installations that might be or are slightly contaminated. It should be noted that the effort required to certify the radiological content of large volumes of material that may in fact be quite bulky and/or irregular is quite high and costly. This situation remains a challenge, as well as an aspect to be taken into account in decisions regarding materials management.

The caution taken by stakeholders in accepting slightly contaminated materials is also found in situations involving the release of facilities and sites from radiological regulatory control. Although there is no directly-applicable international component to these decisions, in that sites and facilities do not move, the experience from the release of other similar sites, perhaps in other countries, has played a role in decisions regarding the definition of release criteria, and the question of “how clean is clean enough?” The increasing desire of stakeholders to enter into decision-making processes regarding site and facility release remains a challenge to the holistic approach suggested by the radiological protection system. It should also be noted that the choice to reuse a nuclear installation for another nuclear use (e.g. decommissioning an old nuclear power plant and replacing it with a modern one) will only postpone the need to make decisions regarding facility and site release.

A more practical issue is the maintaining of safety culture during site and facility decommissioning. Decommissioning operations generally tend to address the most significant sources early (e.g. spent nuclear fuel in nuclear power plants, severely contaminated hot cells in other nuclear or industrial installations, large radiation sources in hospital or industrial facilities, etc.). Once these have been removed, remaining sources are generally significantly smaller, and present less immediate risk to workers. As such, relaxation of safety culture may occur, and could result in less attention being paid to optimisation in the planning and implementation of work. In addition, in that decommissioning operations can take many years, skilled and historically knowledgeable workers may be lost to retirement or change of position, such that institutional memory may suffer. These challenges merit the attention of regulatory and implementation organisations.

It should also be noted that some countries are changing the way in which decommissioning is managed. In most countries the owner and/or the operator of the facility is also responsible for the conduct of decommissioning (including the costs). In some countries, specific organisations have been established to optimise these activities. In a few, decommissioning responsibilities have been

assigned (totally or partially) to a dedicated national management agency. Many approaches to assuring appropriate financing of decommissioning activities are also used. Although these evolutions do not have any direct effect on radiological protection, structural and financial considerations will play a part in radiological-protection decision making.

Future direction/what questions remain?

In principle, there is no significant need to make policy-level adjustments to the existing radiological protection system in order to assure appropriate regulation and application in the decommissioning of radiological contaminated sites and facilities. There is however a clear need to fully ensure the control over such facilities and their nuclear and/or radioactive materials, mostly in the case of delayed decommissioning, including the maintenance of an adequate safety culture to avoid potential radiological risks and/or legacies in the future. Moreover, the development of specific regulatory frameworks for decommissioning, to among other things foster the optimisation of protection, may be necessary. It should finally be noted that as experience with new institutional structures evolves, there will be an increasing need to exchange relevant national experiences.

However, discussions should continue regarding the application of radiological protection principles related to the release of contaminated materials from regulatory controls. The broad principles of exclusion and exemption have existed for some time, and through international discussions have become increasingly clear. Their generic application, however, remains elusive. As such, it will be necessary to continue discussions of how to appropriately balance the needs of international harmonisation, as in the trade of slightly contaminated commodities, with the needs of governments to appropriately address local, specific issues. Complementary approaches to those based on generic dose criteria and specific activity concentrations may be needed to achieve the most effective protection under the circumstances.

Increasing medical exposures

Description of the issue

Under social pressure and rapid technical evolution, the medical use of radiation is growing, and is the largest man-made source of radiation exposure. In developed countries, the average level of radiation exposure due to medical applications is equivalent to approximately 50% of the global average exposure to natural radiation. The latest UNSCEAR report (UNSCEAR, 2000) documented a steady increase, even in developed countries, in the last decades

of the per capita number of medical procedures using radiation, with an associated increase of collective exposure. Changes in the patterns of health care levels in developing countries due to economic development, as well as the advances in technologies, foreshadow further increases.

Although alternative modalities for diagnosis are becoming increasingly available, such as ultrasound, endoscopy and MRI, x-ray examinations remain the most frequent use of ionizing radiation in medicine, and thus the most significant source of medical exposure for the world population. In addition to traditional and more advanced digital radiographic techniques for direct diagnostic examinations, x-ray exposures are increasingly used in interventional radiological techniques, in which imaging plays an essential role in guiding therapeutic procedures or in delivering therapeutic agents.

While the growing use of computed tomography in developed countries has substantially improved the diagnostic assessments of pathological conditions, this has also resulted in an increase of radiation exposure. In the last decade, the availability of improved techniques both in imaging and endovascular operational tools has contributed to the fast growth of interventional radiology. Radiological techniques are not only used to help diagnosis and assessments pre- or/and post-surgical intervention (cardio-angiography, vascular radiology, neuroradiology), but they are also used for therapeutic applications. Hundreds of different types of radiological interventional procedures exist today.

The last comprehensive review of medical exposures, presented in by the already quoted UNSCEAR report, highlights an annual exposure increase, in the mid-nineties, in some developed countries of about 10% for interventional diagnostic, and even more for therapeutic procedures. It is conceivable that since the last UNSCEAR report this trend has reached a larger number of developed countries, and practices are expanding further.

A similar situation is also present in the case of unsealed sources, classically concerning the applications in nuclear medicine. A growing field of applications concern the radioisotope-guided surgery in which the selective absorption by tumours of specific radio-pharmaceuticals is used to guide the biopsy or removal of particular structures. In this cases, often the operator is often not himself trained in radiological protection, or is not assisted by a physician trained in radioprotection, in contrast to nuclear medicine specialists.

Several new techniques have also been introduced in radiotherapy that aim to deliver a dose more directed to the pathological region of the target organ (intensity modulated radiotherapy, therapy with proton and ion beams), thereby

reducing doses to surrounding organs. As these new procedures are more powerful, they require more precise tools in the preparation of the radiotherapy session, particularly for the immobilisation of the patient to assure reproducible accuracy over several treatment sessions, as well as much more realistic and reliable tissue-based treatment plans.

It is worthwhile to mention another growing field of non-conventional applications known as intra-operative radiotherapy (IORT). After the ablation of the tumour, a therapeutic radiation dose is delivered to the tissues surrounding the removed pathological volume while the patient is still in theatre. In this case, however, the surgeon is helped by a specialist in radiotherapy who has been trained in radioprotection. Nonetheless, the unusual environment and circumstances merit specific radioprotection assessments for operators and patients.

The effects of change

The availability of rapidly changing new technologies in medical imaging, using both radiological and radio-isotopic approaches, and economic pressures have resulted in radioprotection issues not being fully taken into account during the introduction of a new apparatus or procedures. For instance, in computed tomography a significant reduction of patient doses has now been achieved by paying attention to the choice of scanning technique parameters, which demonstrates, *a posteriori* the need to address radiological protection issues as early as possible.

Therapeutic treatments, connected with radiological intervention, generally represent alternatives to more invasive or hazardous surgical treatments, but are nonetheless complex. The extensive use of fluoroscopy for guiding surgeons, and of cineradiography for documenting interventions can involve significant periods of patient and operator exposure resulting in relatively high doses. Documented cases of localised doses of several gray, with manifestation of radiation-induced skin injuries, are not uncommon.

Because many developments in the field of radiological intervention are very recent, few surgeons, who are generally trained according to the classical branches of medical sciences, have received training in radioprotection in their curricula or are helped, during the radiological procedure, by a specialist in radiology. This is certainly, together with the objective difficulties of the interventional medical procedure, a possible reason for some lack of awareness in radiological protection that is sometimes seen in the application of the new procedures.

Future direction/what questions remain?

There will most likely be a need to devote resources to assure that radiation protection requirements and optimisation proceed in parallel with technology development and implementation. Benchmarking of equipment, in terms of diagnostic and radiological protection performance, could also be considered from an early stage of equipment development.

Several national and international documents have addressed the problem of radiation safety in interventional procedures, but gaps remain in the implementation and enforcement at the national level by competent authorities. In addition, the measurement and recording of patient doses should be addressed in order to more appropriately stress the importance of radiological protection considerations during the development and deployment of new procedures and technologies.

The problem of radiological protection training remains an open issue. In some countries, regulations require that the individuals responsible for radiological exposures, e.g. physicians and others such as chiropractors, must be properly trained in radiological protection, in other countries the use of radiation diagnostic procedures is allowed as ancillary tools for therapeutic treatment.

Some international actions have been already been adopted. The European Commission published guidelines on education and training in radiation protection for medical exposures, including specific recommendations for interventional practices guided by fluoroscopy, promoting the production of training material, and organising special courses to train interventional cardiologists in radiological protection.

More work must be done, specifically at local level where operators can more easily be targeted. Practical implementation of the optimisation principle should be generalised, relying on structured and quantified approaches. For professionals already in the field, specific training courses on radiological protection and best practice should be organised with mandatory participation. For new operators, specific training courses must be foreseen at the university-level for all the professionals who are allowed to use radiation for whatever reason, i.e. for diagnostic or therapeutic (not only therapy with radiation but also therapy using radiation) purposes.

Radiological emergencies and malevolent actions involving radioactive material

Description of the issue

Radiological emergency situations continue to be of great governmental concern, whether resulting from nuclear or industrial facility accidents,

transportation accidents or malevolent actions. The preparation for such situations has been a priority of the NEA, with its INEX exercise programmes, since the Chernobyl accident.

Radioactive sources are used throughout the world for a wide variety of purposes, notably in industry, medicine and research. The risks posed by such sources vary widely, depending on their activity, the radionuclides they contain, their construction, etc. The risks associated with the planned use of sources are generally well known, and in most cases the use is governed by a license issued by the national regulatory authority.

Although all of the Chernobyl-style nuclear power plants have been or are shortly planned to be shut down, there are still over 400 nuclear power plants in operation around the world, as well as many research reactors and other nuclear installations, and many large sources that are daily in transportation. With the potential growth of the nuclear power industry in the years to come, the need for continued vigilance in nuclear emergency planning and preparedness is if anything increasing.

Over the last decade or so, a number of incidents have been recorded which involve sources that for various reasons were not under control. Such “orphan” sources have been recovered by persons, whether workers or members of the public, unaware of the possible risks. This has led to serious radiation injuries and in some cases to death. Inadvertent melting down of sources discarded as scrap metal has also, in a number of cases, resulted in serious contamination of property and in the need to invoke expensive clean-up procedures.

In addition, the recent terrorist attacks have led to an increased focus on the possibility of sources falling into the wrong hands and substantially changed the nature of the security issues associated with radioactive sources. In particular there is concern about the use of radioactive materials combined with explosive devices designed to cause destruction, damage, or injury by means of the radiation produced by the decay of such material. In most scenarios these devices are unlikely to cause serious physical injuries or health effects. It is likely that the most immediate risk to life or limb would result from the conventional explosive used to disperse the radioactive material rather than from the material itself. Whatever the physical effect, however, such actions, and could potentially have significant psychological impact causing fear and panic, and are more likely to be used as a means of mass disruption rather than as a conventional weapon. Their disruptive effects could be considerable and their economic consequences of having an important urban area contaminated with radiation could be severe. Other the possible terrorist use of large sources

could also result in the significant irradiation of many individuals to levels where deterministic effects would appear, and many more individuals to lesser levels, although resulting in some level of stochastic risk.

The effects of change

The Chernobyl accident highlighted the scale of international effects that nuclear accidents can cause. Since then, international nuclear emergency exercises organised by the NEA have identified many aspects of national and international urgent response planning and preparedness that could be improved. International tests of nuclear emergency communication conventions and mechanisms, organised by the IAEA and the EC, have also helped lead to improvements in these areas.

Since 2001, there have been a number of initiatives at the international level which aim to improve the security of sources. In 2002, the IAEA developed a three year plan of activities aimed at strengthening protection against nuclear terrorism. The plan includes physical protection and other security arrangements for nuclear and other radioactive materials, accountancy of these materials, detections of illicit trafficking, domestically and at international borders, the response to such acts, and activities to facilitate information exchange. The IAEA has also revised its Code of conduct on the safety and security of radioactive sources to take account of international concerns.

In December 2003, the EU enacted the High activity sealed sources (HASS) Directive which when implemented by the Member States will strengthen the control by competent national authorities on those sealed radioactive sources posing the greatest risk and will emphasise the responsibilities of holders of such sources.

In addition to questions related to source security, the possibility of RDDs has also raised the issue of the radiological protection measures to be taken should such an event actually take place. In response to the need for advice, in September 2005 ICRP published a report entitled *Protecting People Against Radiation Exposure in the Event of a Radiological Attack* (ICRP Publication 96). The report aims to provide recommendations for protecting rescuers and affected members of the public against the radiation exposure that might be incurred as a result of such an event.

Future direction/what questions remain?

Maintaining and improving competence through training and exercises will be an ongoing challenge for radiological protection professionals. Adapting responses to most effectively move towards recovery in evolving post-accident situations, particularly as the new threats (e.g. terrorist actions) and new aspects (e.g. emerging focus on mid-and long-term response aspects) will continue to require new experiences and new thinking. A holistic focus on public health issues and surveillance, probably guided by stakeholder involvement, will be needed. The structural effects of such a focus will most likely be felt. Several specific areas will be touched by these aspects.

- Emergency and post-accident rehabilitation preparedness

In general terms, the focus of emergency preparedness arrangements is on people and property in the immediate vicinity of the accident and on people and property at some distance away that might be exposed as a result of the accident. The arrangements relevant to the immediate vicinity of licensed facilities are usually well elaborated and tested through regular exercises. In the case of a radiological attack, it would most likely be targeted at a public area, possibly in an urban environment, where the presence of radiation is not anticipated and where there may be limited preparedness for responding with radiological protection measures. The dispersion conditions routinely assumed for planning emergencies in nuclear facilities may not be applicable to urban scenarios. Additionally, for scenarios involving explosive devices, it may not be immediately known if the event is also associated with radiological, chemical or biological agents, or a combination of contaminants. Therefore, although there are many similarities between the emergency planning and response arrangements for both nuclear accidents and radiological attacks, there are differences which necessitate detailed consideration of the appropriate preparedness and response.

It should also be noted that the NEA INEX 3 Exercise, which focused on consequence management in the post-urgent phase of a radiological contamination situation, indicated that additional international discussion and experience exchange in this area is necessary. Focus on stakeholder involvement in decision-making processes regarding rehabilitation will be a key to achieving accepted radiological protection solutions, but some structural and institutional evolution at the national level may be needed to facilitate these processes.

- Justification

Radiation protection professionals are familiar with the concept of justification which broadly states that the benefits derived from the use of the

radioactive material must outweigh the detriments. They recognise that this concept must incorporate consideration of broader societal issues as well as radiation protection issues. However, while the need to ensure that sources are secure has always been addressed, the extent of the risks associated with orphan sources and the potential for sources to be used for malevolent purposes are still being elaborated. The cost involved in the ultimate secure disposal of sources also raises questions concerning the choice of systems using “machine produced” radiation versus “source produced” radiation in situations where both methods can be used. These elements then need to be incorporated in the overall framework for justification.

- Source stewardship

Some of the incidents which have occurred over the last few years point to the fact that further controls are required to ensure the safety and security of sources over their whole lifetime from the point of manufacture to the point of ultimate disposal. These controls must include appropriate training in radiation protection for management and staff, specific consideration of the physical security of sources, recognition of the importance of an appropriate safety culture supported by management together with consideration of the financial implications of each stage in the lifecycle of the source. While in theory the establishment of financial provision for such sources is possible, in practice it raises a number of difficult questions which need to be resolved. There is also a need for comprehensive databases of all existing sources and for tracking the movement of sources.

- Training and information

It is a requirement of the Basic Safety Standards that those involved in the use of sources of ionising radiation be properly trained in radiation protection and informed as to the risks involved. It is also a requirement that adequate information is given to others directly concerned with the use of sources. This information and training needs to include consideration of security issues associated with the use of sources. It may also be necessary to introduce more stringent security clearance of personnel in certain circumstances.

The need to exercise and train is equally applicable to nuclear emergency situations. Continued expansion of the objectives of such training exercises to meet identified needs, as shown by the evolution from INEX 2 to INEX 3, should be considered.

Maintaining competence, transmission of inheritance

Description of the issue

In the context of a shrinking nuclear industry, over the last two decades the radiological protection community has been pre-occupied with education and with maintaining a sufficient number of new experts in the “educational/experience pipeline”. This is still the case today, although some expansion in the need for radiological protection experts, in the medical, nuclear and industrial areas, seems to be occurring. This raises many questions that could be addressed through many approaches.

Knowledge is an asset to be preserved and transferred to the next generations. Indeed, the radiation protection system is constructed on the basis of practical and empirical data sets, which have long been accumulated as “information”. However, we can not make any decisions based on “information”, but rather we need to rely on the “knowledge” to make decisions on radiation protection issues.

“Knowledge” is an order or disciplinal system to implement radiation protection procedures by interpreting information in the context of complex situations. Knowledge is essentially internalized on the basis of personal experience of trial-and-error processes in the context of various situations. Well experienced radiation protection practitioners know how to control situations in radiation protection, but even for them, it is rather difficult to transfer their knowledge to the next generations.

The problem is the loss of knowledge by the aging and retirement of “first generation practitioners” of radiation protection, who have a lot of experiences and knowledge. If their successful experience was simply transferred to the next generations as information or manuals without contexts or specific situations, our future radiation protection system would be threatened critically, and the potential risk of unexpected accidents would be increased. This experience-based knowledge is essential for less-experienced radiation protection experts to allow them to judge, decide and behave properly in real situations, to prevent small incidences from being irreversible accidents.

Developed countries have enjoyed the benefits of radiation and nuclear power in almost all aspects of their economic and social activities, e.g., energy production, medical and industrial usages, and developments of new sciences and technologies. But even for developed countries, a large trans-generational knowledge gap would be a problem, and thus some effective means must be worked out to prevent this. Potentially more serious is the case of developing

countries, because they have been trying to catch up with developed countries, driven by urgent social and economic reasons. If they simply review data and information (or manuals) without proper knowledge transfer, coordinated international, the potential risks of radiological incidents and accidents would certainly increase.

Developed countries have another important role to play related to radiation protection in new technologies: the promotion of radiation protection at an early stage of these challenging projects. For new technologies, past experiences and knowledge are just references, and in this case, the radiation protection system must be newly constructed from beginning to end. Even if knowledge is well transferred, new fields of radiation protection should be designed and reconstructed step-by-step with caution. In this context, learning from many years of previous experience, we can extract some key lessons that should be considered beforehand in applying the system of radiation protection to emerging sources and exposures that would result from future technologies.

Future technologies may include such things as new fission reactors, fusion reactors, space travel, usage for deep underground cavities, new radiation diagnosis and therapy in advanced medicine, new uses of radiation sources in engineering and industry, and so on.

The effects of change

To fill the knowledge gap, it is also very important to establish the science education program in schools. Since the vast majority of people are not experts in nuclear sciences and radiation protection, it is also important to support the generation of a safety culture among the stakeholders outside of the radiation protection community.

Radiation safety is not only supported by the research scientists, but also by well trained and experienced technical staff. Technicians do not necessarily have scholastic or professional education in nuclear science, but rather come from other fields of science and technology (physics, electronics, mechanics, chemicals, computers, etc.), such that on-the-job training and face-to-face education programmes should also be well-designed from the view point of knowledge management.

Knowledge management has recently been attracting much attention to secure reliable human resources and for the success of the technologies, especially for maintenances and repairs. In this context, knowledge management procedures should be developed as soon as possible.

Future direction/what questions remain?

Knowledge management by leading international organisations will be greatly needed to prevent the loss (or dilution) of the knowledge base, and to prevent the emergence of gaps between generations, or between developed and developing countries. The OECD/NEA CRPPH will be expected to contribute to filling knowledge gaps (e.g. through programmes such as ISOE and INEX). Successful knowledge management will achieve better understanding by the public of radiation and its impacts on health and the environment, as well as the effectiveness of radiation protection procedures internationally. This will allow the radiological protection community to successfully address emerging situations, such as the development of design and operational criteria for new reactors (e.g. Generation IV).

CONCLUSIONS

The detailed understanding of the biological effects of ionising radiation continues to grow, although many uncertainties remain. Research to reduce these uncertainties must continue, but must be framed and focused by an understanding of the possible impacts that research results could have on the principle, policy, regulatory and application aspects of radiological protection. This articulation between radiological protection science and radiological protection principles and concepts has been recognised as a key aspect by the CRPPH, and will be addressed in the coming years.

A key aspect that will affect the practical implementation of radiological protection in many domains (i.e. management of contaminated areas and materials, decommissioning, nuclear emergencies, etc.) will increasingly be the balance between need for broadly accepted international standards, and the need to take case-specific local circumstances into account when making radiological protection decisions. Further, the perspective from which this balance will be viewed seems itself to be broadening, beyond radiological protection to encompass a full scope of public health issues. All of this, particularly taking into account the increasing application of participatory governance and stakeholder involvement in decision-making processes, suggests that institutional structures, processes and programmes will also be challenged and may need some evolution to best respond to social and scientific concerns. The CRPPH has already initiated work in this area.

Looking back over the past 10 to 15 years reveals a series of events and changes that have somewhat shifted the way that radiological protection is implemented, and will certainly affect the future path taken by the profession in addressing radiological protection situations. Social evolution, scientific advancement and implementation experience have all taught us invaluable lessons that can be used to guide the policy, regulation and application of radiological protection in CRPPH member countries, and beyond.

As per its mandate, the CRPPH will continue to scrutinise scientific advances, social evolution and practical experience in a forward-looking, proactive fashion, in order to assist its members to best interpret this knowledge, so as to most appropriately integrate radiation protection into societal decisions.

REFERENCES

The system of radiological protection

NEA (2000g), *A Critical Review of the System of Radiation Protection: First Reflections of the OECD Nuclear Energy Agency's Committee on Radiation Protection and Public Health*, OECD, Paris, 2000.

NEA (2002b), *The Way Forward in Radiological Protection, An Expert Group Report*, OECD, Paris, 2002.

NEA (2003e), *A New Approach to Authorisation in the Field of Radiological Protection: The Road Test Report*, prepared by R.V. Osborne and F.J. Turvey, OECD, Paris, 2003.

NEA (2005a), *The Process of Regulatory Authorisation: A report by the CRPPH Expert Group on the Regulatory Application of Authorisation*, OECD, Paris, 2005.

Comments on ICRP Draft Recommendations

NEA (2003c), *Radiological Protection of the Environment: The Path Forward to a New Policy?* Workshop Proceedings Taormina, Sicily, Italy, 12-14 February 2002, OECD, Paris, 2003.

NEA (2003d), *Radiological Protection of the Environment: Summary Report of the Issues*, OECD, Paris, 2003.

NEA (2003f), *Evolution of the System of Radiological Protection*, Asian Regional Conference, Tokyo, 24-25 October 2002, OECD, Paris, 2003.

NEA (2003g), *Possible Implications of Draft ICRP Recommendations*, OECD, Paris, 2003.

NEA (2003h), *Future Policy for Radiological Protection*, Workshop Proceedings, Lanzarote, Spain 2-4 April 2003, OECD, Paris, 2003.

NEA (2004a), *Future Policy for Radiological Protection: A Stakeholder Dialogue on the Implications of the ICRP Proposals*, Summary Report, Lanzarote, Spain, OECD, Paris, 2004.

Stakeholder involvement in decision making

NEA (1998d), *The Societal Aspects of Decision Making in Complex Radiological Situations*, Workshop Proceedings, Villigen, Switzerland, 13-15 January 1998, OECD, Paris, 1998.

NEA (2001c), *Better Integration of Radiation Protection in Modern Society*, Workshop Proceedings, Villigen Switzerland, 23-25 January 2001, OECD, Paris, 2001.

NEA (2001d), *Policy Issues in Radiological Protection Decision Making*, Summary of the 2nd Villigen (Switzerland) Workshop, January 2001, OECD, Paris, 2001.

NEA (2004b), *Case Studies in stakeholder participation for the 3rd Villigen Workshop – Stakeholder Participation in Decision Making Involving Radiation: Exploring Processes and Implications*, OECD, Paris, 2004.

NEA (2004c), *Summary of the findings of the 3rd Villigen Workshop, Stakeholder Participation in Decision Making Involving Radiation: Exploring Processes and Implications*, OECD, Paris, 2004.

NEA (2004d), *Stakeholder Participation in Decision Making Involving Radiation: Exploring Processes and Implications*, 21-23 October 2003, Villigen, Switzerland, Workshop Proceedings, OECD, Paris, 2004.

Comparative risk

NEA (2000a), *A Comparison of the Carcinogenic Risk Assessment and Management of Asbestos, Nickel and Ionising Radiation*, NEA/CRPPH(2000)11, OECD, Paris, 2000.

NEA (1998a), *Developments in Radiation Health Science and their Impact on Radiation Protection*, OECD, Paris, 1998.

Chernobyl consequences

NEA (1996a), *Chernobyl Ten Years On – Radiological and Health Impact*, An appraisal by the NEA Committee on Radiation Protection and Public health, November 1995, OECD, Paris, 1996.

NEA (2002a), *Chernobyl: Assessment of Radiological and Health Consequences, 2002 Update of Chernobyl: Ten Years On*, OECD, Paris, 2002.

NEA (2006b), *Stakeholders and Radiological Protection: Lessons from Chernobyl 20 Years After*, OECD, Paris, 2006.

Nuclear emergency matters

NEA (1995a), *INEX 1 – An International Nuclear Emergency Exercise*, OECD, Paris, 1995.

NEA (1995b), *The Implementation of Short-term Countermeasures After a Nuclear Accident (Stable Iodine, Sheltering and Evacuation)*, Proceedings of a NEA Workshop, Stockholm, Sweden, 1-3 June 1994, OECD, Paris, 1995.

NEA (1994a), *Probabilistic Accident Consequences Assessment Code, Second International Comparison – Overview Report*, A Joint Report by the OECD Nuclear Energy Agency and the Commission of the European Communities, OECD, Paris, 1994.

NEA (1997a), *Work Management in the Nuclear Power Industry*, A Manual prepared for the NEA Committee on Radiation Protection and Public Health by the ISOE Expert Group on the Impact of Work Management on Occupational Exposure, OECD, Paris, 1997.

NEA (1997b), *Agricultural Aspects of Nuclear and/or Radiological Emergency Situations*, Proceedings of an OECD/NEA Workshop, Fontenay-aux-Roses, France, 12-14 June 1995, OECD, Paris, 1997.

NEA (1998b), *Second International Nuclear Emergency Exercise, INEX 2: Final Report of the Swiss Regional INEX 2 Exercise*, OECD, Paris, 1998.

NEA (1998c), *Nuclear Emergency Data Management*, Proceedings of an International Workshop, Zurich, Switzerland, 13-14 September 1995, OECD, Paris, 1998.

NEA (2000b), *Monitoring and Data Management Strategies for Nuclear Emergencies*, OECD, Paris, 2000.

NEA (2000c), *Methodologies for Assessing the Economic Consequences of Nuclear Reactor Accidents*, OECD, Paris, 2000.

NEA (2000d), *Radiological Impacts of Spent Nuclear Fuel Management Options: A Comparative Study*, OECD, Paris, 2000.

NEA (2000e), *Second International Nuclear Emergency Exercise INEX 2: Final Report of the Finnish Regional Exercise*, OECD, Paris, 2000.

NEA (2000f), *Second International Nuclear Emergency Exercise INEX 2: Final Report of the Hungarian Regional Exercise*, OECD, Paris, 2000.

NEA (2001a), *Experience from International Nuclear Emergency Exercises: The INEX 2 Series*, OECD, Paris, 2001.

NEA (2001b), *Second International Nuclear Emergency Exercise INEX 2: Final Report of the Canadian Regional Exercise*, OECD, Paris, 2001.

NEA (2003a), *Short-term Countermeasures in Case of a Nuclear or Radiological Emergency*, OECD, Paris, 2003.

NEA (2003b), *Effluent Release Options from Nuclear Installations: Technical Background and Regulatory Aspects*, OECD, Paris, 2003.

NEA (2006a), *Stakeholders and Radiological Protection: Lessons from Chernobyl 20 Years After*, OECD, Paris, 2006.

Occupational exposure management

NEA (2005c), *Occupational Exposures at Nuclear Power Plants*, Fourteenth Annual Report of the ISOE Programme 2004, OECD, Paris, 2005.

NEA (2005b), *Optimisation in Operational Radiological Protection*, A Report by the Working Group on Operational Radiological Protection of the Information System on Occupational Exposure, OECD, Paris, 2005.

NEA (2004e), *Occupational Exposures at Nuclear Power Plants*, Thirteenth Annual Report of the ISOE Programme 2003, OECD, Paris, 2004.

NEA (2003i), ISOE Leaflet, OECD, Paris, 2003.

NEA (2003j), *Occupational Exposure Management at Nuclear Power Plants*, Third ISOE European Workshop, Portoroz, Slovenia, 17-19 April 2002, OECD, Paris, 2003.

NEA (2003k), *Occupational Exposures at Nuclear Power Plants*, Twelfth Annual Report of the ISOE Programme 2002, OECD, Paris, 2003.

NEA (2002c), *ISOE – Information System on Occupational Exposure: Ten Years of Experience*, OECD, Paris, 2002.

NEA (2002d), *Occupational Exposures at Nuclear Power Plants*, Eleventh Annual Report of the ISOE Programme 2001, OECD, Paris, 2002.

NEA (2001e), *Occupational Exposures at Nuclear Power Plants*, ISOE Tenth Annual Report, 2000, OECD, Paris, 2001.

NEA (2000h), *Occupational Exposures at Nuclear Power Plants*, ISOE Ninth Annual Report, 1999, OECD, Paris, 2000.

NEA (1999a), *Occupational Exposures at Nuclear Power Plants*, ISOE Eighth Annual Report, 1998, OECD, Paris, 1999.

NEA (1999b), *Occupational Exposures at Nuclear Power Plants*, ISOE Seventh Annual Report, 1997, OECD, Paris, 1999.

NEA (1998f), *Occupational Exposures at Nuclear Power Plants – 1986-1996*, ISOE Sixth Annual Report, OECD, Paris, 1998.

NEA (1997c), *Occupational Exposures at Nuclear Power Plants – 1969-1995*, ISOE Fifth Annual Report, OECD, Paris, 1997.

NEA (1997d), *Work Management in the Nuclear Power Industry*, A Manual prepared for the NEA Committee on Radiation Protection and Public Health by the ISOE Expert Group on the Impact of Work Management on Occupational Exposure, OECD, Paris, 1997.

NEA (1996b), *Occupational Exposures at Nuclear Power Plants – 1969-1994*, ISOE Fourth Annual Report, OECD, Paris, 1996.

NEA (1995c), *Occupational Exposures at Nuclear Power Plants – 1969-1993*, ISOE Third Annual Report, OECD, Paris, 1995.

NEA (1994b), *Nuclear Power Plant Occupational Exposures in OECD Countries – 1969-1992*, ISOE Second Annual Report, OECD, Paris, 1994.

QUALITIES OF THE CRPPH

The CRPPH is a place to:

- Learn from others:
 - views on current issues;
 - approaches to the application of RP principles;
 - identification of national issues, new or emerging, of interest and/or concern.
- Teach and recall the history and context of complex radiological protection issues to younger experts.
- Hold discussions that are unbiased and unconstrained by legal requirements associated with directives or standards.
- Openly share information and experience, both good and bad.
- Identify similarities and differences in national approaches.
- Identify and analyse emerging issues and their possible implications.
- Transform uncertainty into practical applications.

The approach taken by the CRPPH is:

- Pro-active and action-oriented.
- Forward looking.
- Task-oriented and term-limited.
- Flexible in terms of quickly responding to issues identified by the Committee.
- Balanced in terms of science, regulation and operations.
- Focused on serving “users” of radiological protection principles.

The CRPPH helps member countries to test new ideas and approaches, acting as:

- A laboratory for the development and refinement of ideas;
- An unbiased technical resource;
- A sounding board for the discussion of practical aspects.

The CRPPH has developed and advanced several “flagship” issues, including:

- International nuclear emergency exercises (INEX).
- International exchange of occupational exposure management experience – Information System on Occupational Exposure (ISOE).
- Understanding of issues in stakeholder involvement in radiological protection decision making (Villigen).
- Provision of end user input to the development of ICRP recommendations (EGIR, Taormina, Lanzarote).

The CRPPH is a platform for discussion of international co-ordination:

- Identifying areas where harmonisation could be of value.
- Developing approaches to achieve harmonisation.
- Members often participate in other bodies, increasing the opportunity for complimentary work.
- The CRPPH has acted as a “partner” to the ICRP in the development of new recommendations.

The CRPPH is appreciated for its ability to gather different perspectives for the discussion of issues, thus helping to avoid a “monotonic” voice, and to preserve a high capital of confidence in the application of radiological protection. The fact that the Committee can develop consensus views on important issues makes its voice useful to member countries in support of well-founded, national radiological protection actions.

OECD PUBLICATIONS, 2 rue André-Pascal, 75775 PARIS CEDEX 16
Printed in France.