First ICRP Symposium on the International System of Radiological Protection

Bethesda, USA

October 24-26, 2011

ICRP 2011 Symposium and Meeting
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Monday October 24, 2011

Opening Plenary

9:00 to 10:00 in Ballroom FGH

Chair: Claire Cousins, ICRP Chair

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Claire Cousins, ICRP Chair & Addenbrooke's Hospital, UK

Welcome from the Nuclear Regulatory Commission
Kristine L. Svinicki, Commissioner, Nuclear Regulatory Commission, USA

Welcome from the Environmental Protection Agency
James J. Jones, Deputy Assistant Administrator, Office of Air and Radiation, Environmental Protection Agency, USA

Welcome from the Department of Energy
Glenn S. Podonsky, Chief Health Safety and Security Officer, Office of Health Safety and Security, Department of Energy, USA

ICRP Strategic Plan
Claire Cousins, ICRP Chair & Addenbrooke's Hospital, UK

National Council on Radiation Protection and Measurements (NCRP) Scientific Program and Collaboration with ICRP
Thomas Tenforde, President, National Council on Radiation Protection and Measurements, USA

ICRP Programme of Work

10:30 to 13:00 in Ballroom FGH

Chair: Christopher Clement, ICRP Scientific Secretary

Radiation Effects
Julian Preston, ICRP MC and C1 Chair & Environmental Protection Agency, USA

Doses from Radiation Exposure
Hans Menzel, ICRP MC and C2 Chair, Switzerland

Radiological Protection in Medicine
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Application of the Commission's Recommendations
Jacques Lochard, ICRP MC and C4 Chair & Centre d'étude sur l'Evaluation de la Protection dans le Domaine Nucléaire, France

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The System of Radiological Protection – Is it Fit for Purpose?

14:15 to 17:30 in Ballroom FGH

Chair: Abel González, ICRP Vice-chair

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR): The Scientific Basis for ICRP's Work
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Maria Neira, Public Health and Environment Director, World Health Organisation
Emilie van Deventer, World Health Organisation

The System of Radiological Protection: Is it Fit for Purpose?
Jacques Repussard, Director, Institut de Radioprotection et de Sûreté Nucléaire, France

Radiation Protection Issues on Preparedness and Response for a Severe Nuclear Accident: Experiences of the Fukushima Accident
Toshimitsu Homma, ICRP C4 & Japan Atomic Energy Agency

Future Challenges for the Radiation Protection System in the Nuclear Power Industry
Willie Harris, Exelon Nuclear & WNA RP Working Group Chair, USA

A Regulatory Perspective on whether the System of Radiation Protection is Fit for Purpose
Michael Boyd, Environmental Protection Agency, USA

Panel Discussion

Monday October 24, 2011

Opening Plenary

ICRP Strategic Plan

Dr. C. Cousins

ICRP Main Commission Chair
Consultant Interventional Radiologist, Addenbrooke's Hospital, Cambridge, UK

Abstract - ICRP has been in existence since 1928 and has evolved considerably from that time both in its structure and in its scope of work. The founding principles and objectives regarding the System of Radiological Protection are still very much in evidence today. As we move further into the 21st century, with the culture of increased openness and transparency, it is appropriate for ICRP to develop a strategic plan for both the present and the future. The aim of the plan is to give factual information about the membership, structure and operation of ICRP and to highlight strengths, challenges, and initiatives considered important for future work.

National Council on Radiation Protection and Measurements (NCRP) Scientific Program and Collaboration with ICRP

T. S. Tenforde

President, NCRP, 7910 Woodmont Avenue, Suite 400, Bethesda, Maryland 20814;
PH (301) 657-2652, ext. 19; FAX (301) 907-8768

Abstract- I am pleased to have the opportunity to provide introductory remarks at this important symposium on radiological protection organized by ICRP, which is a Special Liaison Organization of NCRP. Reports and Commentaries published in areas related to radiation protection and measurements are listed at http://NCRPpublications.org. Recent work by NCRP has focused in several areas that include (with a listing of publications over the last five years) (1) characterization of ionizing radiation exposures of the U.S. population (Report No. 160); (2) radiation protection in medicine (Report Nos. 168, 159, 155); (3) treatment of persons contaminated with radionuclides (Report Nos. 166, 161, 156); (4) responding to a nuclear or radiological terrorism incident (Report No. 165, Commentary No. 19); (5) uncertainties in external and internal dosimetry and dose reconstruction (Report Nos. 164, 163, 158); (6) radiation protection in space missions (Report Nos. 167, 153) (7) operational radiation safety (Report No. 162); and (8) environmental radiation (Report No. 154). NCRP has many common interests with ICRP in these and related areas of radiation protection and the underlying radiation science. Several members of ICRP are on NCRP's Board of Directors and on scientific committees. NCRP looks forward to expanding our collaborative efforts with ICRP.

ICRP Programme of Work

Radiation Effects

R. J. Preston

ICRP Main Commission and Committee 1 Chair
NHEERL (MD B105-01), U.S. Environmental Protection Agency, Research Triangle Park, NC 27711, USA; PH (919)-541-0276; FAX (919)-541-1525

Abstract - Committee 1 is responsible for providing updates on the biological effects of ionising radiation and developing documents that relate such effects to the needs of radiological protection. The committee addresses issues of risks of cancer and heritable diseases, tissue reactions including dose responses, effects of dose-rate and radiation quality, effects in the embryo/foetus, genetic factors in radiation response, radioepidemiology studies, basic radiobiology mechanisms, as well as uncertainties in providing judgements on radiation-induced health effects. The committee advises the Main Commission on the biological basis of radiation-induced health effects and how epidemiological, experimental and theoretical data can be combined to make quantitative judgements on health risks to humans, particularly at low doses. These estimates are in the form of detriment-adjusted nominal risk coefficients for stochastic (cancer and heritable effects) and tissue reaction (deterministic) effects that are used for radiation protection standards. Most recently, Committee 1 Task groups have addressed issues of: Tissue Reactions and Other Non-cancer Effects of Radiation; Radon and Lung Cancer; Stem Cell Radiobiology. In addition, Committee 1 discusses the most recent information in areas that impact upon the Recommendations forming ICRP Report 103. These include DDREF, non-targeted effects, modulating factors, and radiation sensitivity.

Doses from Radiation Exposure

H. Menzel

ICRP Main Commission and Committee 2 Chair
CERN, European Organization for Nuclear Research, CH-1211 Geneva 23, Switzerland

Abstract - The work of Committee 2 is concerned with the development of reference data and methods for the assessment of internal and external radiation exposure of workers and members of the public. This involves the development of reference biokinetic and dosimetric models, reference anatomical models of the human body, and reference anatomical and physiological data. Following the recent ICRP recommendations work is concentrating on the evaluation of new reference dose coefficients for external and internal exposure including the development and revision of biokinetic models. The Adult Reference Computational Phantoms are being complemented by reference computational paediatric phantoms. The Committee is assisted in this work by two task groups (DOCAL and INDOS). A third Task Group is developing guidance on the use of effective dose in radiation protection and in risk assessments with a focus on medical exposure, jointly with Committees 1, 3 and 4. Proposals will be made for alternatives for risk management in situations where effective dose should not be used. Another Task Group is dealing with the assessment of exposure of astronauts to cosmic radiation in space.

Radiological Protection in Medicine

E. Vañó

ICRP Main Commission and Committee 3 Chair
Radiology Department, Complutense University, Spain

Abstract - Committee 3 of the International Commission on Radiological Protection (ICRP) is concerned with protection in medicine and develops recommendations and guidance on the protection of patients, staff, and the public against radiation exposure in medicine.

The new 2007 recommendations of the ICRP and the update of the document on "Radiological Protection in Medicine" have introduced some minor changes in the application of RP principles in the medical area (e.g. consideration of the higher risk for cataracts, application of diagnostic reference levels for interventional procedures, etc).

Some RP challenges in medicine for staff and for patients are emerging after the recent ICRP Statement issued on April 2011 (annual limit of dose to the eyes and absorbed dose threshold for circulatory disease).

ICRP has published a significant number of documents dealing with RP in medicine during the last 10 years: Recommendations on Education and Training in RP; Preventing accidental exposures in radiation therapy; Dose to Patients from radiopharmaceuticals; Radiation safety aspects of brachytherapy; Release of patients after therapy with unsealed radionuclides; Managing patient dose in digital radiology and in computed tomography; Avoidance of radiation injuries from medical interventional procedures; Pregnancy and medical radiation and Reference levels in medical imaging.

Three new documents will be published in the coming months dealing with pediatric radiology, cardiology and fluoroscopically guided procedures.

The work in progress of the Committee deals with: Radiopharmaceuticals (update); Secondary cancer risk after modern radiotherapy; Charged particle radiotherapy; Justification of the use of ionization radiation in diagnostic imaging and Follow-up of persons accidentally exposed.

Application of the Commission's Recommendations The Activities of ICRP Committee 4

J. Lochard

ICRP Main Commission and Committee 4 Chair
Director of the Centre d'étude sur l'Evaluation de la Protection dans le domaine Nucléaire – CEPN, France

Abstract - ICRP Committee 4 has the responsibility to develop principles, recommendations and guidance on the protection of man against radiation exposure and to consider their practical application in all exposure situations. The Committee also acts as a major point of contact between the ICRP structure and other international organisations and professional bodies concerned with protection against ionising radiation.

During the present current 4-year term the work of Committee 4 is structured according three priorities:

- To develop advice on the implementation of the new recommendations (ICRP Publication 103) and to contribute to their dissemination: review and update of past publications, application of the radiological protection principles in particular exposure situations.
- To review the ethical and social values underlying the principles and concepts of the radiation protection system: precautionary principle, equity, tolerability of risk, sustainable development, etc.

- To enhance the dialogue and cooperation with international organisations and professional societies.

The current program of work of the Committee includes a series of Task Group on the application of the Commission's Recommendations to screening activities for security purposes, the geological disposal of long-lived solid radioactive waste, naturally occurring radioactive material, radon in dwellings and at workplaces, and the protection of aircraft crew against cosmic radiation exposure.

Radiological Protection of the Environment

R. J. Pentreath

ICRP Main Commission and Committee 5 Chair
Plymouth Marine Laboratory, Prospect Place, The Hoe, Plymouth, PL1 3DH, UK

Abstract- The development of a systematic approach to protection of the environment has required a number of basic steps to be taken, including a discussion of what objectives could reasonably be set, together with an examination of how existing knowledge could best be used in order to achieve them. It has required bold decisions to be made, new modelling to be undertaken, and new data sets to be compiled. Equally challenging, however, has been the need to fold the entire subject area into an expanded system originally developed for the protection of human beings. There are, inevitably, a number of data gaps; and further decisions need to be made. But the priority now is to examine how this approach to protection of the environment can be used in practice. With an intensifying world-wide debate about the environmental merits of different forms of energy production, it would seem imperative that the various practices involved in the nuclear fuel cycle are able to demonstrate, clearly and independently, their own actual or potential impact on the environment. The ICRP now has the basic means for such evaluations to be made, and further developments in this system will reflect the experience of its practical application.

The System of Radiological Protection – Is it Fit for Purpose?

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR): The Scientific Basis for ICRP's Work

M. Crick

Secretary of the Committee, UNSCEAR secretariat, Vienna, Austria

Abstract- The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is charged by the United Nations General Assembly with evaluating the levels and trends of all sources of exposure to ionizing radiation, and the corresponding health and environmental effects. Its assessments are conducted on behalf of the 193 Member States of the United Nations and represent the consensus of the United Nations system on these matters. It provides the platform on which radiation protection paradigms are founded.

This paper will highlight, with examples, issues related to the role of ICRP that are affecting the work of the Committee. These issues include the misunderstanding and misuse of detriment-adjusted nominal risk coefficients, and the ability to attribute health effects to radiation exposure. They also include problems in following trends of exposure when dose quantities change, the use of dose quantities for assessing deterministic effects, and confusion created by the concepts of equivalent dose and effective dose, both measured in units of Sievert.

The System of Radiological Protection - A Medical and Public Health Perspective

E. van Deventer, M. Pérez and Z. Carr, and M. Neira

World Health Organization, Department of Public Health and Environment. 20, avenue Appia, 1211 Geneva 27, Switzerland. TEL + (41) 22 791 3950; FAX + (41) 22 791 4123

Abstract- The system of radiological protection aims to control radiation risks without unduly limiting the potential benefits for individuals and society. Achieving this balance becomes particularly challenging in medicine. Today, ionizing radiation is key in medical imaging and cancer treatment. However, inappropriate or incorrect handling can lead to unnecessary or unintended radiation exposures with potential health hazards for patients and medical staff. Justification and optimization are the two pillars of radiological protection in health care. In fact, these two principles are implicit in the notion of good medical practice. Indeed, good health services are those which deliver safe and effective health interventions to those that need them, when and where needed, with minimum waste of resources. However, health professionals are not necessarily familiar with these two principles and have low awareness of radiation doses and risks. Improving radiation safety culture of medical practice is crucial for several reasons: (i) to ensure that patients benefit from the use of radiation in health care, (ii) to contribute to a more cost-effectively allocation of health resources and (iii) to empower the health profession by encouraging an appropriate use of radiation in health care. Messages need to be tailored for health authorities in order to facilitate the application of the system of radiological protection in health care settings. Hence, efforts are needed to improve the dissemination of ICRP recommendations in the health sector. From a public health perspective, such communication efforts should also encompass existing and emergency exposure situations. This is particularly relevant to support the implementation of the International Basic Radiation Safety Standards (BSS).

The System of Radiological Protection: Is it Fit for Purpose?

J. Repussard, A. Rannou[1], P. Scanff and J.-R. Jourdain

Institut de radioprotection et de Sûreté Nucléaire, 31 avenue de la division Leclerc, BP 17, 92262 Fontenay-aux-Roses cedex; PH +33 1 58 35 88 88

Abstract- Over the last decades, ICRP members have developed out of their joint expertise a unique operational framework which is today used worldwide, albeit not always in its latest version, by radiological protection professionals to guide their actions in the various exposure situations which can occur, from planned occupational situations to accidental circumstances. In the case of France, the implementation of ALARA principles and ICRP recommendations, as transferred into the National regulatory system, has led over time to a remarkable reduction in the exposure of workers (nuclear industry, non-nuclear industry, medical applications, research) both in terms of number of overexposed individuals and dose received. However, as modern societies focus their concerns on the protection of individuals rather than populations as a whole, and on potential detriments related to chronic exposures at very low dose rates, and as science provides new avenues for the investigation of biological radiation-induced events, new questions arise which challenge the current radiation protection system: what is the true shape of the dose/effect relationship at such low doses which are sometimes close to natural environmental exposures, sometimes higher as currently in some areas of Japan? What are the non-cancer effects, if any, associated with such exposures? How can the individual sensitivity factor to radiation be taken into account? Beyond these questions lies the fundamental need to better investigate the mechanisms which are induced by radiation on sub-cellular components, at intercellular and organ or whole organism level, including stress response mechanisms. Such advanced low dose effects research needs international support and coordination, such as being developed through the European MELODI association, to achieve the results which could then be accrued into the future editions of ICRP recommendations.

Radiation Protection Issues on Preparedness and Response for a Severe Nuclear Accident: Experiences of the Fukushima Accident

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[1] ICRP Committee 4
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[2]Risk Analysis and Applications Group, Nuclear Safety Research Centre, Japan Atomic Energy Agency, Tokai-mura, Ibaraki-ken 319-1195 Japan; PH (029) 282 6139; FAX (029) 282 6147

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[4]Risk Analysis and Applications Group, Nuclear Safety Research Centre, Japan Atomic Energy Agency, Tokai-mura, Ibaraki-ken 319-1195 Japan; PH (029) 282 5208; FAX (029) 282 6147

Abstract- A risk of severe accidents in nuclear power plants that has been discussed in nuclear safety regulation emerged at the Fukushima Daiichi nuclear power plant. The severe accident risk in nuclear power plants can be managed as a potential exposure in the context of planned exposure situations. In the discussion of safety goals for nuclear installations in Japan, metrics used were only individual health risks but the Fukushima accident indicated the importance of societal risk such as countermeasures needed to protect individuals and land contamination rather than individual risk. Although the national emergency plan in nuclear power plants in Japan was heavily dependent upon a computer prediction system such as source terms and environmental radiation dose calculations, the urgent protective actions have been effectively taken on the basis of the plant conditions at the early stage of emergency exposure situations. That procedure is recommended by the IAEA safety requirements. In the absence of criteria for long-term protective actions in the emergency preparedness guideline, Nuclear Safety Commission of Japan advised the government to use reference levels in emergency exposure situations recommended by ICRP for determining the temporary relocation of the residents in the heavily contaminated area. The paper discusses the radiation protection issues on preparedness and response for severe nuclear accidents from experiences of the Fukushima accident.

Future Challenges for the Radiation Protection System in the Nuclear Power Industry

W.O. Harris, CHP

Exelon Nuclear Corporation, 200 Exelon Way, Kennett Square, PA 19348 PH (610) 765-5350

Abstract- The Nuclear Power industry in the United States has made significant improvements in radiation protection over the past decade. These improvements have resulted in significant reduction in individual and collective radiation exposures, reduced number of events, such as overexposures, and improved overall radiological, industrial, and nuclear safety. This paper will discuss challenges facing the radiation protection system in the US nuclear power program due to resources and staffing, regulatory environment, and recent events in the industry. Currently, the United States Nuclear regulatory commission is evaluating the need to revise the existing regulations to improve the alignment between the existing regulations and ICRP 103 recommendations. There are several areas that will be addressed, such as the occupational and public dose limits, radiation quantities and units, and internal doses. In addition, several recent events, in the nuclear power industry, both domestic and international, may have profound impact on the radiation protection system for nuclear power operations. The paper will review the impacts from these events in light of the potential changes associated with updating the existing regulations used in the United States to the ICRP 103 methodology.

A Regulatory Perspective on whether the System of Radiation Protection is Fit for Purpose

M. A. Boyd

Office of Radiation and Indoor Air, U.S. Environmental Protection Agency, Mail Code 6608J, 1200 Pennsylvania Ave., Washington, DC 20460, USA; PH 1 (202) 343-9395; FAX 1 (202) 343-2304

Abstract- The system of radiation protection has its origins in the early efforts to protect people from x-rays and radium. It was at the Second International Congress of Radiology in Stockholm in 1928 where the first radiation protection recommendations were adopted. The system of protection steadily evolved as new sources of exposure arose and our understanding of radiation-related health risks improved. Safeguarding against these risks has required regulators to set enforceable (i.e., measurable) standards. From erythema dose to tolerance dose, critical organ dose to effective dose equivalent, and now effective dose, the units used to set these limits have evolved along with the science underpinning them. Similarly, the definition of the person or group being protected has changed – from standard man to reference man to reference person, with age and gender differences now explicitly taken into account. As regulators look towards implementing the changes in ICRP Publication 103, there remain questions about how to translate an optimization-based system of constraints and reference levels into the more familiar regime of enforceable limits. Nevertheless, since the new recommendations are refinements of a system that itself more than adequately did the job it was designed to do, so too will the new system of radiation protection be fit for purpose.

Tuesday October 25, 2011

Tissue Reactions: Low Dose Risks

8:30 to 10:10 in Ballroom FG

Chair: Julian Preston, ICRP MC and C1 Chair

Epidemiology of Non-Cancer Effects at Moderate and Low Doses
Mark Little, National Cancer Institute, USA

Radiobiology Biology and Radiation Protection
Jolyon Hendry, ICRP C1, UK

Mechanisms of Radiation-Induced Cardiovascular Disease
Fiona Stewart, ICRP C1 & Netherlands Cancer Institute

Radiation Cataracts
Norman Kleiman, Columbia University, USA

Radiation Effects: Modulating Factors and Risk Assessment

10:40 to 12:20 in Ballroom FG

Chair: John Boice, ICRP MC

Radiation Effects: Modulating Factors and Risk Assessment: An Overview
Richard Wakeford, ICRP C1 & University of Manchester, UK

Residential Radon, Smoking and Lung Cancer
Sarah Darby, ICRP C1 & University of Oxford, UK

Biologically-Based Dose-Response Models in Cancer Risk Assessment
Suresh Moolgavkar, University of Washington, USA

Genetic Predisposition to Radiation-Related Cancer and Potential Implications for Risk Assessment
Alice Sigurdson, ICRP C1 & National Cancer Institute, USA

Applications of Effective Dose

8:30 to 10:10 in Ballroom H

Chair: John Harrison, ICRP C2

Effective Dose: A Radiation Protection Quantity
Hans Menzel, ICRP MC and C2 Chair, Switzerland

Effective Dose: A Flawed Concept that Could and Should be Replaced
David J. Brenner, Columbia University Medical Center, USA

Effective Dose and Risks from Medical X-ray Procedures
Mikhail Balonov, ICRP C2 & Institute of Radiation Hygiene, Russia

Radiation Protection in Space

10:40 to 12:20 in Ballroom H

Chair: Hans Menzel, ICRP MC and C2 Chair

Uncertainty Analysis in Space Radiation Protection
Frank Cucinotta, National Aeronautics and Space Administration, USA

Radiation Transport Calculations for Cosmic Radiation
Akira Endo, ICRP C2 & Japan Atomic Energy Agency

Assessment of Radiation Exposure of Astronauts in Space
Günther Dietze, ICRP C2, Germany

Radiological Protection in Computed Tomography

13:50 to 15:30 in Ballroom FG

Chair: Eliseo Vañó, ICRP MC and C3 Chair

CT Scanning: The Good, the Bad and the Ugly
Fred Mettler, ICRP MC Emeritus, New Mexico Federal Regional Medical Center, USA

ICRP and IAEA Actions on Radiation Protection in CT
Madan Rehani, ICRP C3 & International Atomic Energy Agency

Minimising Medically Unwarranted CT Scans
David J. Brenner, Columbia University Medical Center, USA

Paediatric CT
Pek-Lan Khong, ICRP C3 & University of Hong Kong, China

Prevention of Accidents in Radiation Therapy

16:00 to 17:40 in Ballroom FG

Chair: Madan Rehani, ICRP C3

Accident Prevention in Day-to-day Clinical Radiation Therapy Practice
Mario Baeza, ICRP C3 & Instituto de Radiomedicina, Chile

Impact of Complexity and Computer Control on Errors in Radiation Therapy
Benedick Fraass, Cedars-Sinai Medical Center, Los Angeles, USA

Prioritization of Quality Management Activities Based on What is Reasonably Achievable and Optimally Beneficial to Patients
M. Saiful Huq, University of Pittsburgh Cancer Institute and Medical Center, USA

Tools for Risk Assessment in Radiation Therapy
Pedro Ortiz Lopez, ICRP C3 & International Atomic Energy Agency

The Scientific Basis for Reference Animals and Plants

13:50 to 15:30 in Ballroom H

Chair: Jan Pentreath, ICRP MC and C5 Chair

The Biological Basis for Protection of the Environment
Carl-Magnus Larsson, ICRP C5 & Australian Radiation Protection and Nuclear Safety Agency

Dosimetry for Reference Animals and Plants: Current State and Prospects
Alexander Ulanovsky, ICRP C5 & Helmholtz Zentrum München, Germany

RBE and Radiation Weighting Factors in the Context of Animals and Plants
Kathryn Higley, ICRP C5 & Oregon State University, USA

Environmental Protection in Practice

16:00 to 17:40 in Ballroom H

Chair: Carl-Magnus Larsson, ICRP C5

Clarifying and Simplifying the Management of Environmental Exposures under Different Exposure Situations
Jan Pentreath, ICRP MC and C5 Chair, UK

Regulatory Experience in Applying a Radiological Environmental Protection Framework for Existing and Planned Nuclear Facilities
Steve Mihok, Canadian Nuclear Safety Commission

Application of Radiological Protection Measures to Meet Different Environmental Protection Criteria
David Copplestone, ICRP C5 & University of Stirling, UK

Tuesday October 25, 2011

Tissue Reactions: Low Dose Risks

Epidemiology of Non-Cancer Effects at Moderate and Low Doses

M. P. Little

Radiation Epidemiology Branch, National Cancer Institute, Executive Plaza South, 6120 Executive Boulevard MSC 7238, Rockville, MD 20852-7238 USA

Abstract- There is a well established association between high doses of ionizing radiation exposure and damage to the heart and coronary arteries, although only recently have studies with high quality individual dosimetry been conducted that would enable quantification of this risk adjusting for concomitant chemotherapy. The association between lower dose exposures and late occurring circulatory disease has only recently begun to emerge in the Japanese atomic bomb survivors and in various occupationally-exposed cohorts, and is still controversial. Excess relative risks per unit dose in moderate and low dose epidemiological studies are somewhat variable, possibly a result of confounding and effect modification by well known (but unobserved) risk factors; at least for endpoints other than heart disease there is statistically significant (p<0.001) heterogeneity between the risks.

For some time it has been known that high radiation doses of 1 Gy or more could induce posterior subcapsular cataract. Accumulating evidence from the Japanese atomic bomb survivors, Chernobyl liquidators, US astronauts and various other exposed groups suggest that nuclear and cortical cataracts can also be induced by ionising radiation. The accumulating evidence implies a linear dose response, although modest thresholds (of no more than about 0.6 Gy) cannot be ruled out.

A variety of other non-malignant effects have been observed after moderate/low dose exposure in various groups, in particular respiratory and digestive disease and CNS (and in particular neuro-cognitive) damage. However, because these are generally only observed in isolated groups, or because the evidence is excessively heterogeneous, these associations must be treated with caution.

Radiation Biology and Radiation Protection

J. H. Hendry

ICRP Committee 1
Adlington, Macclesfield, UK.

Abstract- For protection purposes, the biological effects of radiation are separated into stochastic effects (cancer, hereditary effects) presumed to be unicellular in origin, and tissue reactions due to injury in populations of cells. The latter are deterministic effects, renamed tissue reactions in the 2007 ICRP recommendations because of the increasing evidence of the ability to modify responses after irradiation. Tissue reactions become manifest either early or late after doses above a threshold dose, which is the basis to recommended dose limits for avoiding such effects. Latency time before manifestation is related to cell turnover rates and tissue proliferative and structural organisation. Threshold doses have been defined for practical purposes at 1% incidence of an effect. In general, threshold doses are lower for longer follow-up times because of the slow progression of injury before manifestation, and may be higher if doses are fractionated or protracted. Recent studies have revealed that for both circulatory disease and lens cataracts, the threshold dose is very small and not significantly different for acute and protracted exposures. This could be the case if doses ≤ the threshold dose caused only single-hit-type events not modified by repair/recovery phenomena, or if different mechanisms of injury are involved at low and high doses.

Mechanisms of Radiation-Induced Cardiovascular Disease

F. A. Stewart

ICRP Committee 1
Experimental Therapy, The Netherlands Cancer Institute, Plesmanlaan 121, 1066CX Amsterdam, The Netherlands

Abstract- Epidemiological studies have shown a clear association between therapeutic doses of thoracic irradiation and increased risks of cardiovascular disease in long-term cancer survivors. Survivors of Hodgkin's lymphoma and childhood cancers, for example, show 2 to >7-fold increases in risks for cardiac deaths after total tumour doses of 30-40 Gy, given in 2-Gy fractions. The risks of cardiac mortality increase linearly with dose, although for cardiac doses <5 Gy there are large uncertainties. Experimental studies show that doses of ≥ 2 Gy induce the expression of inflammatory and thrombotic molecules in endothelial cells. In the heart this causes progressive loss of capillaries and eventually leads to reduced perfusion, myocardial cell death and fibrosis. Laboratory animal data are supported by clinical studies demonstrating regional perfusion defects in non-symptomatic breast cancer patients 6 months after radiotherapy. In large arteries, radiation (≥ 2 Gy) initiates atherosclerosis and predisposes to the formation of unstable lesions, which are prone to rupture and may cause a fatal heart attack or stroke. After doses < 2Gy, it seems likely that other mechanisms are responsible for cardiovascular effects. Persistent increases in pro-inflammatory cytokines and long-term impairment of T-cell-mediated immunity may well be involved. Monocyte killing and increased levels of chemoattractant proteins may also play a role in initiation and progression of atherosclerosis.

Radiation Cataracts

N. J. Kleiman

Eye Radiation and Environmental Research Laboratory (ERERL), Department of Environmental Health Sciences, Mailman School of Public Health, Columbia University, 722 West 168th Street, New York, NY 10032; PH (212) 305-6748; FAX (212) 305-6748

Abstract- Until very recently, ocular exposure guidelines were based on the assumption that radiation cataract is a deterministic event requiring threshold doses generally greater than 2 Gy. This view was, in part, based on older studies which generally had short follow-up periods, failed to take into account increasing latency as dose decreased, had relatively few subjects with doses below a few Gray and were not designed to detect early lens changes. Newer findings, including those in populations exposed to much lower radiation doses and in subjects as diverse as astronauts, medical workers, A-bomb survivors, accidentally exposed individuals and those undergoing diagnostic or radiotherapeutic procedures, strongly suggest dose-related lens opacification at significantly lower doses. These observations resulted in a recent re-evaluation of current lens occupational exposure guidelines and a proposed lowering of the presumptive radiation cataract threshold to 0.5 Gy and occupational lens exposure limit to 20 mSv/yr, regardless of whether an acute, protracted or chronic exposure. Experimental animal studies support these conclusions and suggest a role for genotoxicity in radiation cataract development. New guidelines are likely to have significant implications for occupational exposure and the need for eye protection, for example in fields such as interventional medicine, and are also likely to influence current research efforts concerning the cellular and molecular mechanisms underlying cataractogenesis.

Effective Dose: A Radiation Protection Quantity

H. Menzel

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Abstract - Modern radiation protection is based on the principles of justification, limitation and optimization. Assessment of radiation risks for individuals or groups of individuals is, however, not a primary objective of radiological protection. The implementation of the principles of limitation and optimization requires an appropriate quantification of radiation exposure. ICRP has introduced effective dose E as the principal radiological protection quantity to be used for setting and controlling dose limits for stochastic effects in the regulatory context and for the practical implementation of the optimization principle. Effective dose is the tissue-weighted sum of radiation weighted organ and tissue doses of a reference person from exposure to external irradiations and internal emitters. The specific normalized values of tissue weighting factors are defined by ICRP for individual tissues and used as an approximate sex-averaged representation of the relative contribution of each tissue to radiation detriment of stochastic effects from whole-body low-LET irradiations. The rounded values of tissue and radiation weighting factors are chosen by ICRP on the basis of available scientific data from radiation epidemiology and radiation biology and they are therefore subject to adjustment as new scientific information becomes available. Effective dose is a single, risk-related dosimetric quantity and is used prospectively for planning and optimization purposes and retrospectively for demonstrating compliance with dose limits and constraints. In practical radiation protection it has proven to be extremely useful.

Effective Dose: A Flawed Concept that Could and Should be Replaced

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Abstract- Effective dose is used to characterize the generic risk of a total body radiation-induced stochastic health detriment. The effective dose represents flawed science: two of the most important reasons are that the tissue-specific weighting factors used to calculate effective dose are a subjective mix of different endpoints, and that the marked and differing age dependencies for different health detriment endpoints are not taken into account. Effective dose is prone to misuse, particularly in the field of radiology. It is suggested that effective dose could be replaced by a new quantity, effective risk, which, like effective dose, is a weighted sum of equivalent doses to different tissues; unlike effective dose, where the tissue-dependent weighting factors are a set of generic, subjective committee-defined numbers, the weighting factors for effective risk would simply be evaluated tissue-specific lifetime cancer risks per unit equivalent dose. The resulting "effective risk", which has the potential to be age- and gender-specific if desired, would perform the same comparative role as effective dose, be just as easy to estimate, be less prone to misuse, be more directly understandable, and would be based on solid science.

Effective Dose and Risks from Medical X-ray Procedures

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Abstract – The radiation risks from a number of medical X-ray examinations (radiography, fluoroscopy and computer tomography) were assessed as a function of the age and sex of the patient on the base of organ doses and compared with calculations done using effective dose. Radiation risk models described in ICRP Publication103 and UNSCEAR Report 2006 (Annex A) were used for risk calculations. Methodologically similar but not identical dose and risk calculations were performed independently of each other at IRH, Russia, and HPA, UK and led to similar conclusions. Radiogenic risk of stochastic health effects following various X-ray procedures substantially varied with patient age and sex to different extents depending on which body organs were irradiated. Generally, risk of radiation-induced stochastic health effects in children is higher (up to a factor of four) than in adults, and risk in senior patients is lower by a factor of ten or more than in younger people. If risk is assessed based on effective dose it is underestimated for children of both sexes by a factor that reaches four for girls undergoing thorax examinations. For adults, effective dose overestimates risk by a factor up to 2.5 and for senior patients by a factor of ten and more. The significant sex- and age-dependence of radiogenic risk for different cancer types is an important consideration for radiologists when planning X-ray examinations. While effective dose was not intended to provide a measure of risk associated with such examinations, it may be sufficient to make simple adjustments to the nominal risk per unit effective dose to account for age and sex differences.

Radiation Effects: Modulating Factors and Risk Assessment: An Overview

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Abstract- The risk coefficients – the increased risks of cancer generated by the receipt of a unit dose of ionising radiation – that underlie the structure of radiological protection recommended by the ICRP are summary risk estimates inferred from risk models describing the dose-responses for a number of different types of cancer. These summary risk estimates give the overall average lifetime excess risk of cancer for a general population and for a working population, and are designed for a practical, internationally applicable system of protection (e.g. one with common dose limits and constraints). However, it is recognised that the summary risk estimates represent averages over a range of factors that modify the risk, such as race, sex, age-at-exposure, attained-age and time-since-exposure, and age-at-exposure is explicitly accommodated in the difference between the general population and working population risk coefficients used by the ICRP. Since the background risk of certain cancers varies between races, of importance is how the risk observed in a population composed of a particular race is transferred to another population. Beyond these intrinsic factors are a variety of lifestyle factors. For example, if the risk from radiation exposure is not independent of whether an individual smokes tobacco then the radiation risk coefficient will differ between smokers and non-smokers. This variation extends to other exposures, such as alcohol, drugs and certain genetic conditions, and is likely to be of relevance to those other factors that affect the risk of certain cancers, such as diet and obesity. Finally, it should not be forgotten that the system of radiological protection recognises that the type of radiation (e.g. γ-ray, α-particle), and for some radiations the dose-rate, affects the risk per unit absorbed dose, and that these also represent averaging for the purposes of protection.

Residential Radon, Smoking and Lung Cancer

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Abstract- Recent epidemiological data enable the extent to which radon causes lung cancer in ordinary homes to be estimated. They also provide insight into the way in which cigarette smoking modifies the risk of radon-related lung cancer. These new data have substantial implications for optimum strategies for the control of radon-related lung cancer.

Biologically-Based Dose-Response Models in Cancer Risk Assessment

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Abstract- The process of cancer risk assessment involves much more than low-dose extrapolation. In particular, an understanding of how temporal factors, such as detailed exposure histories, affect cancer risk is essential to making rational risk assessment decisions. These considerations are particularly important for radiation risk assessment. Yet, despite the fact that Haber's law rarely holds for human carcinogens, conventional statistical methods generally relate risk to cumulative exposure rather than the detailed pattern of exposure. BBDR models provide one way to incorporate detailed exposure histories in the analyses of epidemiologic data in cancer. The central problem in cancer epidemiology is to understand how the processes of mutation accumulation, and clonal expansion and selection, which characterize multistage carcinogenesis, are modified by genetic background and environmental factors. Although the paradigm is now firmly established, most epidemiologic studies of cancer incorporate ideas of multistage carcinogenesis neither in their design nor in their analyses. In this largely non-technical talk, I will give examples to show that using ideas of multistage carcinogenesis can yield insights into epidemiologic studies of cancer that would be difficult or impossible to get from conventional methods. I will focus on cohort studies of lung cancer. I will argue that the target of estimation in cohort studies should be not the relative risk, but the hazard function. The traditional statistical approaches to analyses of epidemiologic studies are based on the Cox proportional hazards model. Proportionality of hazards is a strong assumption, however, which is rarely checked, but often violated. BBDR models offer an alternative to the traditional approaches for analyses of epidemiologic data and important insights for cancer risk assessment.

Genetic Predisposition to Radiation-Related Cancer and Potential Implications for Risk Assessment

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Abstract-Several lines of evidence suggest that risk estimates for cancer associated with radiation exposure are composed of individuals who are more and less inherently susceptible to radiation's carcinogenic effects. This concept has been proposed as one potential reason the risk relationship between most human solid cancers and radiation is linear rather than some other hypothesized relationship, such as sub-linear. Currently it is probably premature to seriously consider ascribing susceptibility to any particular genetic background, such as polymorphic variants in *ATM*, because their function is incompletely understood and most often are rare so they cannot account for a large proportion of cancers from radiation exposure. On the other hand, the idea to sum the number of potentially deleterious variants discovered through genome-wide scans irrespective of their likely functional magnitude seems to be regaining favour. One could imagine summing all potentially deleterious variants for radiation-associated cancer risk in all genes based on sequencing and create a susceptibility score. But to be more accurate, risks cannot be aggregated over all cancers since some show very different dose-response relationships and some solid cancers are thought to be relatively resistant to radiation effects. Also, risks may differ at low vs. high doses or dose-rates, at young or older ages at exposure or by other host characteristics. Such risk models would also differ between leukaemia and the radiation-associated solid cancers, but could certainly be done if the human biologic and outcome data were extensive enough. The enormous effort to develop such risk models should not be underestimated. Nevertheless, given the recent use of genome-wide scans to discover radiation-

related second cancer variants such as *PRDM1*, it is promising to speculate that the predictive set may not be long. If a radiosensitivity assay emerges with high predictive value for radiation associated cancer types, then genome-wide association studies could be applied in a similar way as that used to recently identify the *PMAIP1/Noxa* gene's association with sensitivity to the radiomimetic agent bleomycin. At the moment these undertakings would require significant resources and stronger relationships or predictive values than seen at present and are likely premature for inclusion in radiation risk assessment.

Uncertainty Analysis in Space Radiation Protection

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Abstract: Space radiation is comprised of high energy and charge (HZE) nuclei, protons, and secondary radiation including neutrons. The uncertainties in estimating the health risks from galactic cosmic rays (GCR) are a major limitation to the length of space missions, the evaluation of potential risk mitigation approaches, and application of the ALARA principle. For long duration space missions, risks may approach radiation exposure limits, therefore the uncertainties in risk projections become a major safety concern and methodologies used for ground-based works are not deemed to be sufficient. NASA limits astronaut exposures to a 3% risk of exposure induced death (REID) and protects against uncertainties in risks projections using an assessment of 95% confidence intervals in the projection model. We discuss NASA's approach to space radiation uncertainty assessments and applications for the International Space Station (ISS) program and design studies of future missions to Mars and other destinations. Several features of NASA's approach will be discussed. Radiation quality descriptions are based on the properties of radiation tracks rather than LET with probability distribution functions (PDF) for uncertainties derived from radiobiology experiments at particle accelerators. The application of age and gender specific models for individual astronauts is described. Because more than 90% of astronauts are never-smokers, an alternative risk calculation for never-smokers is used and will be compared to estimates for an average U.S. population. Because of the high energies of the GCR limits the benefits of shielding and the limited role expected for pharmaceutical countermeasures, uncertainty reduction continues to be the optimal approach to improve radiation safety for space missions.

Radiation Transport Calculations for Cosmic Radiation

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Abstract- Radiation environment inside and near to spacecrafts consists of various components of the primary radiation in space and secondary radiation produced by the interaction of the primary radiation with the walls and equipment of the spacecrafts. Radiation fields inside astronauts are different from those outside them, because of the body-self shielding as well as the nuclear fragmentation reactions occurring in the human body. Several computer codes have been developed to simulate the physical processes of the coupled transport of proton, high charge and energy (HZE) nuclei, and the secondary radiation produced in atomic and nuclear collision processes in matter. These computers codes have been applied to space radiation protection: shielding design of spacecrafts and planetary habitats, simulation of instrument and detector response, analysis of absorbed doses and quality factors in organs and tissues, and study of biological effects. The presentation will focus on the methods and computer codes used for radiation transport calculation of cosmic radiation, and their application to analysis of radiation fields inside spacecrafts, evaluation of organ doses in the human body, and calculation of dose conversion coefficients using the ICRP reference phantoms defined in ICRP Publication 110.

Assessment of Radiation Exposure of Astronauts in Space

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Abstract- The paper is based on data and concepts which have been collected and discussed by an ICRP Task Group in their work of preparing an ICRP Report on "Assessment of radiation exposure of astronauts in space". The primary radiation field in space, the galactic cosmic radiation and the solar radiation, with its broad range of charged particle types and energies is very complex and is additionally modulated due to interactions of the primary radiation with materials of a space vehicle. The high component of heavy ions in the field compared to the situation on Earth has consequences for the concept of protection quantities and quantities used in measurements. Radiation quality of heavy ions need to be considered in more detail than the simple procedure applied on Earth where a single radiation weighting factor of 20 is used for all heavy ions and all energies. For space applications the use of the quality factor concept seems more appropriate and better correlated with exposure risks. Further on, some data will be presented about the measurement techniques used for the assessment of doses to astronauts in space.

The Biological Basis for Protection of the Environment

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Abstract- The approach to protection of the environment may vary considerably depending on ethical basis, methodological approach and identification of endpoints and protective targets. The approach may not involve a biological basis at all but focus on the abiotic component of the environment. The ICRP reviewed these issues in its Publication 91, "A framework for assessing the impact of ionising radiation on non-human species", published in 2003. At the same time, ICRP proposed that: a possible future ICRP system addressing environmental assessment and protection would focus on biota; that the system should be effect-based so that any reasoning about *adequate* protection would be derived from firm understanding of harm at different exposure levels; and that the system should be based on data sets for reference animals and plants, or RAPs. ICRP has thus chosen to approach environmental protection on the basis of biology and further developed the approach in Publications 103, 108 and 114. This paper explores the biological basis for the ICRP system of environmental protection from the viewpoints of: effects endpoints of concern; the hierarchy of biological organisation, adequate and appropriate protective targets, and the derivation of benchmark dose (rates) to guide protective efforts.

Dosimetry for Reference Animals and Plants: Current State and Prospects

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Abstract- The enormous diversity of non-human biota is a specific challenge when developing and applying dosimetric models for assessing exposures to flora and fauna from environmental radioactivity. Dosimetric models, adopted by the ICRP, provide dose conversion coefficients for a large variety of biota, including the ICRP's Reference Animals and Plants. The models use a number of simplified approaches, often ignoring presumably insignificant details. Simple body shapes with uniform composition and density, homogeneous internal contamination, limited set of external radiation sources for terrestrial animals and plants, truncation of radioactive decay chains – these are a few examples of simplifying assumptions underlying the dose conversion coefficients included in Publication 108 of the ICRP. Still, many specific assessment tasks require dosimetry data for non-standard species or irradiation scenarios. The further development of dosimetric models aims at the implementation of flexible choices of animals and plants as well as of their irradiation conditions (e.g. trees), the more systematic consideration of internal exposures from radionuclides concentrated in specific organs, task-oriented choice of decay chains based on the ICRP Publication 107. Extensive set of non-human dosimetry data might require specific software to facilitate a fast, accurate, and flexible selection of pertinent dose conversion coefficients for specific assessment tasks.

RBE and Radiation Weighting Factors in the Context of Animals and Plants

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Abstract- Radiation weighting factors have long been employed to modify absorbed dose as part of the process of evaluating radiological impact to humans. Their use represents an acknowledgement of the fundamental difference in energy deposition patterns of charged and uncharged particles and how this can translate into varying degrees of biological impact. Weighting factors used in *human* radiation protection are derived from a variety of end points taken from *in vitro* experiments that include human and animal cell lines, as well as *in vivo* experiments with animals. None the less, the application of radiation weighting factors in the context of dose assessment of animals and plants is not without some controversy. Specifically, radiation protection of biota has largely focused on limiting deterministic effects, such as reduced reproductive fitness. Consequently the application of conventional stochastic-based radiation weighting factors (when used for human protection) appears inappropriate. While based on research, radiation weighting factors represent the parsing of extensive laboratory studies on relative biological effectiveness (RBE). These studies demonstrate that the magnitude of a biological effect depends not just on dose, but also other factors including the rate at which the dose is delivered, the type and energy of the radiation delivering the dose, and most importantly the *endpoint* under consideration. This presentation discusses the efforts taken to develop a logical, transparent, and defensible approach to establishing radiation weighting factors for use in assessing impact to non-human biota, and the challenges found in differentiating stochastic from deterministic impacts.

CT Scanning: The Good, the Bad and the Ugly

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Abstract- The rapid growth of CT scanning and associated dose over the last few decades went largely unappreciated. The first alert came from ICRP Committee 3 in Publication 87 which published in 2001. There are many obvious benefits from CT scanning, particularly in the setting of trauma and cancer management. CT scanning has completely replaced intravenous urograms and many nuclear medicine lung scans. The variability in doses, protocols and justification of procedures remains problematical. A number of deterministic effects have been due to poorly designed protocols and lack of awareness of the associated absorbed dose. Studies on the radiogenic cancer potential of CT scans are underway. There are also efforts to standardize protocols, record doses and educate the medical community.

ICRP and IAEA Actions on Radiation Protection in Computed Tomography (CT)

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Abstract – The ICRP has published two Annals on managing patient doses in CT (Publication 87, in 2001) and in multi-detector CT (Publication 102 in 2007). It was way back in 1999 when the ICRP presaged that CT use is set to expand tremendously with resultant patient organ doses in the range where there is increased probability of cancer. The actions by the ICRP were aimed at creating awareness about issues of radiation risks, dealing with specific clinical applications and providing guidance. Giving recommendations to manufacturers was also an important objective. The increase in usage and resulting incidents in recent years have confirmed and rather surpassed speculations. The IAEA has played a complementary role in creating awareness through its website http://rpop.iaea.org which has become increasingly popular and is currently accessed in 90 countries; has projects in many developing countries on patient dose assessment and dose management, the results of which have been published, and has established networks on radiation protection of children in different parts of the world. The combined actions of these two organizations, along with the involvement of a number of major international organizations which form part of the IAEA's International Action Plan for the Radiological Protection of Patients, provides both top down and bottom up coverage.

Minimizing Medically Unwarranted CT Scans

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Abstract- The annual number of CT scans is increasing rapidly, particularly in health-care level I countries. The concern is that organ doses from CT are typically far larger than those from conventional x-ray exams, and there is persuasive evidence of a small but significant increased cancer risk at typical CT doses. Because CT is such a superb diagnostic tool and because individual CT risks are small, the CT benefit/risk balance is generally by far in the patient's favour. Nevertheless, CT should operate under the ALARA (As Low As Reasonably Achievable) principle, and opportunities exist to reduce the significant population dose associated with CT. The first opportunity is to reduce the dose per scan, and improved technology has much potential here. The second opportunity is selective replacement of CT with other modalities, such as for many head and spinal exams (e.g. to MRI), and for diagnosing appendicitis (e.g. selective use of ultrasound + CT). Finally, a fraction of CT scans could be avoided entirely, as indicated by CT decision rules. Widespread use of CT clinical decision rules represents a powerful approach for slowing down the increase in CT usage, because they have the potential to overcome many of the major factors that result in medically-unwarranted CT scans.

Radiation Protection in Paediatric CT

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Abstract- It is well accepted that there is higher risk per unit of radiation dose for the development of cancer in infants and children compared to adults, due to the longer life expectancy for any harmful effects of radiation to manifest and the fact that developing organs and tissues are more sensitive to the effects of radiation. CT examinations may involve relatively higher radiation doses; the absorbed doses to organs and tissues can sometimes approach or exceed the levels known from epidemiological studies to increase the probability of cancer development. Thus, in justification, imaging techniques that do not employ the use of ionizing radiation should always be considered as a possible alternative, e.g. ultrasonography for the abdomen, and MRI for detailed information of the soft tissues, nervous system, or bone marrow. Dose reduction should be optimized by adjustment of scan parameters (mA, kVp and slice thickness) according to patient weight or age. For the purpose of minimizing radiation dose exposure, noisier images, if sufficient for radiological diagnosis, should be accepted. Attention should also be paid to optimizing study quality; this may be improved by image post-processing to facilitate radiological diagnoses and interpretation. Acceptable quality also depends on the structure and organ being examined and the clinical indication for the study. Finally, improvements in CT technology are promising in further reducing patient dose.

Environmental Protection in Practice

Clarifying and Simplifying the Management of Environmental Exposures under Different Exposure Situations.

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Abstract- The ICRP now recognises three different exposure situations, but in all three the release of radionuclides into the natural environment leads to exposures of non-human species, as well as having the potential for exposures of the general public. Each release may therefore need separate evaluations of these two consequences in order to clarify what the relevant objectives of protection are, and how they can be achieved. But the need to meet more than one objective should not necessarily lead to a more complicated regulatory system. Indeed, with regard to low level routine discharges from most nuclear plants, there would appear to be scope for simplifying the entire system, to protect humans and biota, by using both discharge consent and specified Radionuclide Environmental Quality Standards for water, soil, and air in a manner similar to that used to regulate other, major, non-nuclear industries. In contrast, however, with regard to existing exposure situations, different objectives need to be evaluated independently. And in emergency situations, it should be made clear as to what consequences different actions will have, for humans and for the environment, in order to communicate clearly with the public at large as events unfold.

Regulatory Experience in Applying a Radiological Environmental Protection Framework for Existing and Planned Nuclear Facilities

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Abstract- Frameworks and methods for the radiological protection of non-human biota have been evolving rapidly at the ICRP and through various European initiatives. The IAEA is soon expected to incorporate a requirement for environmental protection in a revision of its Basic Safety Standards. In Canada, the CNSC has been legally obligated to prevent unreasonable risk to the environment since 2000. Licensees have therefore been meeting generic legal requirements to demonstrate adequate control of releases of radioactive substances for the protection of both people and biota for many years. In the USA, in addition to the generic requirements of the EPA and NRC, DOE facilities have also had to comply with specific dose limits after a standard assessment methodology was finalized in 2002. Canadian regulators developed a similar framework for biota dose assessment through a regulatory assessment under the Canadian Environmental Assessment Act in the late 1990s. This framework has been applied extensively since then to satisfy legal requirements under the CEAA and the NSCA. Selected examples of recent practices in assessing doses to biota in both countries are compared here and discussed relative to the approaches being considered elsewhere. After roughly a decade of experience in applying these methods in North America, it is clear that simple methods are fit for purpose and can be used for making regulatory decisions for existing and planned nuclear facilities.

Application of Radiological Protection Measures to Meet Different Environmental Protection Criteria

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Abstract-The Commission recognises that there is no simple or single universal definition of 'environmental protection' and that the concept differs from country to country and from one circumstance to another. However, there is an increasing need to be able to demonstrate that the environment is protected from radioactive substances released under authorisation, for various reasons, such as for wildlife conservation requirements, or wildlife management for commercial reasons, or simply as part of pollution control. The Commission is developing the concept of *Representative Organisms,* which may be identified from any specific legal requirements or from more general requirements to protect local habitats or ecosystems. Such organisms may be the actual objects of protection or they may be hypothetical, depending on the objectives of the assessment. They may be similar to, or even congruent with, one or more of the Reference Animals and Plants (RAPs). Where this is not the case, then attempts can be made to consider to what extent the *Representative Organisms* differ from the nearest RAP, in terms of known radiation effects upon it, basic biology, radiation dosimetry, and pathways of exposure. This paper discusses the practical implications of such an approach.

Prevention of Accidents in Radiation Therapy

Accident Prevention in Day-to-Day Clinical Radiation Therapy Practice

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Abstract: Nearly 50-60% of cancer patients will undergo radiotherapy at some moment. Around 85% of the world's population lives in developing countries served by approximately only 30% of the world's radiotherapy facilities. It has been suggested that a megavoltage unit machine is required for every 500 new treatment courses per year, while others estimate that a machine is needed for every 300 new treatments. However these numbers do not necessarily take into account the development of new technologies and treatment modalities, which are more time and staff consuming. ICRP has emphasized that "purchasing new equipment without a concomitant effort on education and training and on a programme of quality assurance is dangerous" thus "the decision to implement a new technology for radiation therapy should be based on a thorough evaluation of the expected benefits, rather than being driven by the technology itself". It has been estimated that the rate of serious mistakes could be as high as 0.2%, which is several orders of magnitude higher that the rate reported for commercial aviation. So how safe is safe? Therefore, the development of a culture of safety is critical and requires efforts in education and training which could be hard in overloaded departments.

Impact of Complexity and Computer Control on Errors in Radiation Therapy

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Abstract- A number of recent publications in both the lay and scientific press have described major errors in patient radiation treatments, and this publicity has galvanized much work to address and mitigate potential safety issues throughout the radiation therapy planning and delivery process. The complexity of modern radiotherapy techniques and equipment, including computer-controlled treatment machines and treatment management systems, as well as sophisticated treatment techniques which involve intensity modulated radiation therapy (IMRT), image-guided radiation therapy (IGRT), stereotactic body radiation therapy (SBRT), volumetric modulated arc therapy (VMAT), respiratory gating, and others, leads to concern about safety issues related to that complexity. This presentation illustrates the relationship of complexity and computer control to various safety problems and errors which have been reported, and describes studies which address the issue of these modern techniques and whether their complexity does in fact result in more errors or safety-related problems. Clinical implications of these results are discussed, as are some of the ways the field should respond to the on-going concerns about errors and complexity in radiation therapy.

Prioritization of Quality Management Activities Based on What is Reasonably Achievable and Optimally Beneficial to Patients

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Abstract- Modern radiotherapy makes use of many machines and techniques with the goal of delivering a highly conformal dose of radiation to a 3D target volume while at the same time minimizing the dose to an acceptable level to surrounding healthy tissue. To accomplish this goal, new complex treatment planning and delivery technologies and procedures are routinely introduced into the clinic. As treatment methods become complex and technologically intensive, the number and sophistication of possible quality management activities, tests, and measurements continually grow. New approaches are being developed in radiation therapy practice to address the quality management needs of both existing and emerging technologies with finite resources. These are based on risk assessment that examines the entire radiation therapy process. They reflect jointly the probability of a failure occurring and the severity should it occur. Thus, they allow a radiotherapy department to develop a systematic quality management program that acknowledges its current level of technology and clinical practice, and balances patient safety and treatment quality with available resources. This paper will describe methods for development and prioritization of such quality management activities.

Tools for Risk Assessment in Radiation Therapy

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ICRP Committee 3
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Abstract- While the benefits from radiotherapy are unquestionable, from the safety perspective, radiotherapy has unique features: it is the only application of radiation, in which humans are intentionally delivered very high radiation doses. Despite of the fact that radiotherapy equipment is provided with well standardized series of safety interlocks, safety in radiotherapy remains heavily dependent on human actions, with a large interaction among different professionals of a multidisciplinary team, involved in a large number of steps. A step by step itinerary is suggested to prevention of accidental exposures in radiation therapy: 1) the first key element is the allocation of responsibilities to qualified professionals and the design a programme on quality and safety; without these key elements, no radiotherapy practice should be operated; 2) the second step is to use the lessons from accidental exposures to test whether the programme of quality and safety is robust enough against these types of events; publications of IAEA and ICRP provide a collection of lessons to facilitate this step; 3) the third step is aimed at finding other latent risks by posing the of “what else could go wrong” or “what other potential hazards might be present” in a systematic, anticipative manner; methods to do this are briefly described in publication no. 112 of the ICRP.

Wednesday October 26, 2011

Dose Constraints and Reference Levels

8:30 to 10:10 in Ballroom FGH
Chair: Jacques Lochard, ICRP MC and C4 Chair

Dose Constraints in Occupational Radiation Protection - Regulations and Practices
Anne McGarry, ICRP C4 & CRPPH Chair & Radiological Protection Institute of Ireland

Global Nuclear Industry Views: Challenges Arising from the Evolution of the Optimization Principle in Radiological Protection
Sylvain St-Pierre, World Nuclear Association

Survey on the Use of Dose Constraints and Reference Levels Made in the Context of the European ALARA Network
Stephen Fennell, Radiological Protection Institute of Ireland

Reference Levels in the Context of Fukushima
Kazuo Sakai, ICRP C5 & National Institute of Radiological Sciences, Japan

Radiological Protection in Waste Management

10:40 to 12:20 in Ballroom FG
Chair: Wolfgang Weiss, ICRP C4

IAEA Safety Standards on Disposal of Radioactive Waste
Magnus Vesterlind, International Atomic Energy Agency

Radioactive Waste Management in France, Safety Demonstration Fundamentals
Gérald Ouzounian, Agence nationale pour la gestion des déchets, France

NRC Regulations for Geological Disposal of Radioactive Wastes
Timothy McCartin, Nuclear Regulatory Commission, USA

Report of the ICRP TG 80 "Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste"
Wolfgang Weiss, ICRP C4 & Federal Office for Radiation Protection, Germany

Experience in Implementing ICRP Recommendations

13:50 to 15:30 in Ballroom FG
Chair: Jaiki Lee, ICRP MC

Stakeholder Involvement with Development and Implementation of ICRP Recommendations: The NEA Experience
Ted Lazo, Nuclear Energy Agency

IRPA's Perspective
Ken Kase, International Radiation Protection Association

Revision of the international BSS: Building on ICRP's Philosophy
Renate Czarwinski, International Atomic Energy Agency

Past Experience and Future Plan in Korea
Kunwoo Cho, Korea Institute of Nuclear Safety

U.S. NRC Discussion of Options to Revise Radiation Protection Regulations
Donald Cool, ICRP C4 & Nuclear Regulatory Commission, USA

Radiological Protection in NORM

10:40 to 12:20 in Ballroom H

Chair: Peter Burns, ICRP C4

Development of a NORM Management Strategy for the Oil & Gas Industry
Michael Cowie, Saudi Aramco, Saudi Arabia

Advances in NORM Management in Norway and the Application of ICRP Publication 103 Recommendations
Astrid Liland, Norwegian Radiation Protection Authority

The Situation of NORM in Non-uranium Mining in China
Liu Hua, ICRP C4 & National Nuclear Safety Administration, China

NORM Survey in Argentina
Analia Canoba, Autoridad Regulatoria Nuclear, Argentina

Protection against Radon in Workplaces

13:50 to 15:30 in Ballroom H

Chair: John Cooper, ICRP MC

Lung Cancer Risk from Radon Exposure: Contribution of Recently Published Uranium Miners Studies
Margot Tirmarche, ICRP C1 & Institut de Radioprotection et de Sûreté Nucléaire, France

Radon Dosimetry
John Harrison, ICRP C2 & Health Protection Agency, UK

Radon and the System of Radiological Protection
Jean-Francois Lecomte, ICRP C4 & Institut de Radioprotection et de Sûreté Nucléaire, France

Industry Views on ICRP Radon Statement
John Takala, Cameco Corporation, Canada

Symposium Summary and Conclusions

16:00 to 17:45 in Ballroom FGH

Chair: Claire Cousins, ICRP Chair

Radiological Protection of the Environment
Jan Pentreath, ICRP MC and C5 Chair, UK

Constraints and Reference Levels, NORM and Waste
Jacques Lochard, ICRP MC and C4 Chair & Centre d'étude sur l'Evaluation de la Protection dans le Domaine Nucléaire, France

Radiological Protection in Medicine
Eliseo Vañó, ICRP MC and C3 Chair & Complutense University, Spain

Effective Dose & Radiological Protection in Space
Hans Menzel, ICRP MC and C2 Chair, Switzerland

Tissue Reactions & Modulating Factors and Risk Assessment
Julian Preston, ICRP MC and C1 Chair & Environmental Protection Agency, USA

Protection Against Radon in Workplaces
John Cooper, ICRP MC & Health Protection Agency, UK

The System of Radiological Protection & Experience in Implementing ICRP Recommendations
Abel González, ICRP Vice-chair & Autoridad Regulatoria Nuclear, Argentina

Symposium Closing Remarks
Claire Cousins, ICRP Chair & Addenbrooke's Hospital, UK

Wednesday October 26, 2011

Dose Constraints and Reference Levels

Dose Constraints in Occupational Radiation Protection - Regulations and Practices

A. McGarry

ICRP Committee 4
Chair of Nuclear Energy Agency Committee on Radiation Protection and Public Health (NEA - CRPPH) & Radiological Protection Institute of Ireland
Edward Lazo, Nuclear Energy Agency

Abstract - The concept of dose constraints was first introduced by the ICRP in Publication 60 to assist with the optimisation of protection in occupational exposure: "*An important feature of optimisation is the choice of dose constraints, the source-related values of individual dose used to limit the range of options considered in the procedure of optimisation*" (ICRP, 1991).

In Publication 103, the ICRP re-enforced the principle of optimisation of radiation protection using dose constraints or reference levels, and emphasised that it should be applicable in a similar way to all exposure situations – planned, emergency and existing: "*The concepts of a dose constraint and reference level are used in the process of optimisation of protection to assist in ensuring that all exposures are kept as low as reasonably achievable, societal and economic factors being taken into account. Constraints and reference levels can thus be described as key parts in the optimisation process that will ensure appropriate levels of protection under the prevailing circumstances*." In planned exposure situations the dose term dose constraint is used, and in emergency and existing exposure situations it is called reference level.

During the development of the new recommendations, dose constraints was one of the concepts that generated the most questioning and confusion among stakeholders. To further explore the issues involved, the NEA Committee on Radiation Protection and Public Health (CRPPH) mandated its Expert Group on Occupational Exposure (EGOE) to study the current use of dose constraints in the management of occupational exposures in practice, and their implementation in regulatory frameworks.

The work of the EGOE is presented. It addresses

- Experience of interpretation and implementation of dose constraints in occupational radiation protection and in regulatory operational frameworks following ICRP Publication 60;
- Operational and regulatory issues that may arise with the implementation of dose constraints as described in ICRP Publication 103; and

Suggestions for operational objectives and uses of dose constraints in light of the recommendations of ICRP in Publication 103.

Global Nuclear Industry Views: Challenges Arising from the Evolution of the Optimization Principle in Radiological Protection

S. Saint-Pierre

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Abstract- Over the last few decades, the steady progress achieved in reducing planned exposures of both workers and the public have been admirable in the nuclear sector. However, the disproportionate focus on tiny public exposures associated with normal operations came at a high price, and the quasi denial of a risk of major accident and related weaknesses in emergency preparedness and response came at even higher price. Fukushima has unfortunately taught us that radiological protection (RP) for emergency and post-emergency can be much more than a simple evacuation that lasts 24 to 48 hours with people safely returning to their homes shortly afterward. On optimization of planned exposures, the reality is that nowadays margins for further dose reductions in the nuclear sector are small and the smaller the dose, the greater the extra effort needed to further reduce doses. If not sufficiently cautious in the use of RP notions like dose constraints, there is a real risk of challenging nuclear power technologies beyond safety reasons. For nuclear new build, it is the optimization of key operational parameters of nuclear power technologies (not RP) that is of paramount importance in order to improve their overall efficiency. On optimization of emergency & post-emergency exposures, the only 'show in town' in terms of RP policies improvements has been the issuance of the ICRP new general recommendations. However, no matter how genuine these improvements were, they have not been road tested to the practical reality of severe accidents. Post-Fukushima, there is a compelling case to review the practical adequacy of key RP notions such as reference levels for workers and the public, evacuation, sheltering, and the likes, and to amend these notions with a view to make the international RP system more useful in the event of a severe accident. The global nuclear industry is committed to help overcoming the above key RP issues as part of the RP community's upcoming deliberations towards a more efficient international RP system.

Survey on the Use of Dose Constraints and Reference Levels Made in the Context of the European ALARA Network

S.G. Fennell

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Abstract - The European ALARA Network (EAN) was established in 1996 by the European Commission to further specific European research on topics dealing with optimisation of radiation protection, as well as to facilitate the dissemination of good ALARA practices within the European industry, research and medical sectors. The network has now become self sustainable and is registered as a not-for-profit association under French law. Twenty countries participate in the network, bringing together experts in radiation protection from a variety of stakeholders across Europe including regulatory authorities, research organisations and service providers. The EAN publicises its activities and disseminates information via an ALARA newsletter published twice a year and through its website, as well as holding workshops on specific ALARA topics every 18 months. In addition the EAN has established a number of sub-networks which focus on specific areas of interest. One of these networks, the European Radiation Protection Authorities Network (ERPAN), was established in 2005 to promote the exchange of information between regulatory authorities across Europe.

The concept of a dose constraint was included in the 1996 European Basic Safety Standards Directive which defined it as "*a restriction on the prospective doses to individuals which may result from a defined source, for use at the planning stage in radiation protection whenever optimization is involved"*.

The Directive also stated that "*it should be used, where appropriate, within the context of optimization of radiological protection*". As all member states of the European Union were required to implement this Directive in national legislation, the use of dose constraints should now be well established throughout Europe.

In 2010 EPRAN undertook a survey to review how the concept of dose constraints had been implemented across Europe. In particular, the survey focused on their use in the context of the optimisation of occupational exposure in the non-nuclear sector. The results of this survey were included in a report published by the NEA in September 2011 and presented at this symposium.

Reference Levels in the Context of Fukushima: Lessons Learned and Challenges to the Radiation Protection System

K. Sakai

ICRP Committee 5
National Institute of Radiological Protection, Japan

Abstract - After the nuclear accident, a number of reference levels were adopted, including one regarding the use of playground of schools in Fukushima. Considering the band of 1-20 mSv/year recommended by ICRP for public exposure for existing exposure situation, Japanese authorities set 20 mSv/year on April 19 as a "start line" for reducing the dose to school children. When the level of 20 mSv/year was announced, the meaning of a reference level was explained at a press conference. However, the "20mSv/year" led considerable confusion among the general public and some experts. They thought that the school children would be exposed to 20 mSv/year and compared this value with the dose limit of 1 mSv/year for planned exposure situations. Factually, later in May, based on the measurement of ambient dose rates in schoolhouses as well as playground, actual dose was estimated around 10 mSv/year at most.

Another issue was raised with regard to the higher radiosensitivity of children. In ICRP recommendations a higher risk coefficient is given to the whole population compared to the adult one, because it includes children, a sub-population of higher sensitivity. The point of argument was whether lower reference levels are to be set, when only children are considered.

Including this example, some lessons learned and challenges to the current radiation protection system will be discussed.

Development of a NORM Management Strategy for the Oil & Gas Industry

M. I. Cowie, K. A, Mously, O. Fageeha, R. Nassar

Environmental Protection Department, Saudi Aramco, Dhahran 31311, Saudi Arabia

Abstract- It has been established that Naturally Occurring Radioactive Material (NORM) accumulates at various locations along the oil/gas production process. Components such as wellheads, separation vessels, pumps and other processing equipment can become NORM contaminated, and NORM can accumulate in sludge and other waste media. Improper handling and disposal of NORM contaminated equipment and waste can create a potential radiation hazard to workers and the environment. Saudi Aramco Environmental Protection Department initiated a program to identify the extent, form and level of NORM contamination associated with the company operations. Once identified the challenge of managing operations which had a NORM hazard was addressed in a manner that gave due consideration to workers and environmental protection as well as operations' efficiency and productivity. The benefits of shared knowledge, practice and experience across the oil & gas industry are seen as key to the establishment of common guidance on NORM management. This paper outlines Saudi Aramco's experience in the development of a NORM management strategy and its goal of establishing common guidance throughout the oil & gas industry.

Advances in NORM Management in Norway and the Application of ICRP Publication 103 Recommendations

A. Liland

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Abstract - The largest quantities of radioactive discharges and radioactive waste in Norway comes from the oil and gas sector, even though smaller quantities of other NORM waste are also produced by industrial or mining processes. The Gulen final repository for radioactive waste from the oil and gas industry was opened in 2008 and has a capacity of 6000 tons.

As of 1 January 2011 a new regulation was enforced whereby radioactive waste and radioactive pollution is now regulated under the Pollution Control Act. This means that radioactive waste and radioactive pollution are now regulated in the same manner as all other pollutants and hazardous wastes. The regulation defines two sets of criteria: a lower value for when waste is considered radioactive waste and a higher value, in most cases, for when this waste must be disposed off in a final waste repository. As an example, waste containing $\geq$ 1 Bq/g of Ra-226 is defined as radioactive waste while radioactive waste containing $\geq$ 10 Bq/g of Ra-226 must be disposed off in a final repository. Radioactive waste between 1 and 10 Bq/g can be handled and disposed of by waste companies who have a licence for handling hazardous substances according to the Pollution Control Act or the Radiation Protection Act.

The goal of the new regulation is that all hazardous waste should be handled and stored in a safe manner, not posing unnecessary risk to humans or the environment.

The presentation will elaborate on the scientific basis used to develop the new regulation of radioactive waste and the principles of NORM management in Norway in view of the ICRP Publication 103 recommendations.

The Situation of NORM in Non-Uranium Mining in China

L. Hua

ICRP Committee 4
Dept. of Nuclear Safety Management, Ministry of Environment Protection, China

Abstract -The Ministry of Environmental Protection (MEP) in China is responsible for regulatory control on radiation protection to Naturally Occurring Radioactive Material (NORM). The natural radiation by human activities is the major contributors to the public and occupational exposure in China. Some significant achievements concerning NORM exposure and control have been made.

The paper introduces the first national pollution sources census for target year 2007 in China. In the census, total 11 kinds of non-uranium ores were included, e.g. rare earth, niobium/ tantalum, zircon and its oxides, tin, lead /zinc, copper, aluminum, vanadium, iron and steel, phosphate, and coal including coal gangue. From the census, there are 1433 companies in China to produce ores, raw materials. The radioactivity of uranium, thorium-232, and Radium-226 in non-uranium ore products and raw material are various.

The paper also introduce more detailed a NORM site in Baotou, Inner Mongolia, which is the largest rare earths deposit in China. The ores are rich in radioactive elements, with a 0.01-0.05% concentration of ThO_2 and a 0.0005-0.002% of U_3O_8. The deposit has been mined for more than 50 years. Ores are transported by train to refinery plants in Baotou to process for products of iron and steel, REO and their compounds. Meanwhile, the large amount of NORM residues produced is being regulated and controlled. At the present time, waste rocks are about 560×10^6 t and stored in the on-site waste rock dumps around the open pits, tailings are 149×10^6 t and stored in tailing pond, ferrous slags are about 55×10^6 t and stored in a ferrous slag dump, RE slags are 437.3×10^3 t and stored in the Radioactive Waste Storage Facility. Most of waste water after treated, is discharged in tailing pond and then pumped to milling plant for reuse. Waste gas after off-dust cleaning is discharged to environment. A substantial amount of blast furnace iron slags have been made into cement, concrete, bricks or used directly for highway construction. However, it raises serious environmental concerns. Environmental radiation monitoring and assessment have been made recently.

The paper concludes that NORM is the major contributor to the exposure of public and workers. To take effective measures to lower the dose and to strengthen the regulation on NORM is very important.

NORM Survey in Argentina

C. Canoba1

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Abstract- A survey programme was initiated several years ago with the aim to estimate NORM exposure incidence on workers in several different activities carried out through the country, in oil and gas industry, gold mining, spas and in caverns. This work presents the procedures, methods employed and the results found up to date from the survey including protection and remedial actions recommended when deemed necessary. Radium isotope concentrations measured in some samples were well above the exemption values established by the Standards. Elevated radon levels (above action level value established for workplaces) were detected in gas facilities, in the gold mine and cavern. The values detected were informed to the pertinent authorities as well as the facilities in order to take actions to reduce concentrations below the action level. In relation with the spas, almost all values of the geothermal waters analysed were below the corresponding guidance levels. Regarding regulatory aspects, ARN is the technical institution that gives advice to the Government in these issues. In this work the results obtained within the companies surveyed are presented with the aim of evaluating the presence of NORM and the exposure of workers.

IAEA Safety Standards on Disposal of Radioactive Waste

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Division of Radiation, Transport and Waste Safety
International Atomic Energy Agency (IAEA)

Abstract- The IAEA safety standards provide a robust framework of fundamental principles, requirements and guidance to ensure safety in activities and facilities where ionizing radiation is utilized or present.

An overview of the safety standards most relevant for management (predisposal and disposal) of radioactive waste and spent fuel will be presented. Emphasis will be given to the recently published safety requirements publication SSR-5, Safety Requirements on Disposal Radioactive Waste.

This Safety Requirements publication sets out the safety objective and criteria for the disposal of radioactive waste and establishes the requirements that must be satisfied in the disposal of radioactive waste. It applies to the disposal of radioactive waste of all types by means of emplacement in designed disposal facilities, subject to the necessary limitations and controls being placed on the disposal of the waste and on the development, operation and closure of facilities.

A short overview will be given of on-going safety harmonization projects for near-surface (PRISM) and geological disposal (GEOSAF), with focus on suggested approaches for developing the safety case for disposal facilities.

Radioactive Waste Management in France, Safety Demonstration Fundamentals

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Abstract- The main challenge in the development of the safety case for the deep geological disposal is associated with the long periods of time over which high-level and intermediate-level long-lived wastes remain hazardous. Over such periods as hundreds of thousands years, a wide range of events and processes may occur. These events and processes are characterised by specific timescales. For example the timescale for heat generation is much shorter than any geological timescale. To reach a high standard of reliability in the safety case, it is therefore essential to get a thorough understanding and description of the sequence of events and processes likely to occur over the lifetime of the repository. It becomes then possible to assess the capability of the repository to fulfil its safety functions. However, again due account of the long periods of time and of the complexity of the events and processes likely to occur, uncertainties related to all processes, data and models also need to be understood and addressed.

According to the French safety guidance published in 2008 by the safety authority, the fundamental protection principles at the basis of the design are:

- protection of human beings and the environment against possible aggressions related to radioactive waste ;
- limitation of an eventual radiological impact level as low as reasonably possible.

The protection of human beings and the environment is understood, above all, as a protection against the specific risk linked to radioactive waste, that is, radioactivity and its induced effects. The compliance with radioprotection objectives is verified through radiological impact assessments.

The protection against other aggressions due to wastes and, in particular, potential chemical risk, due to the presence of toxic elements may also be considered. Its assessment is mainly covered through its chemical behaviour in the natural system and through the one of its radiological impact

For the long term, the main safety indicator remains the committed individual effective dose at the outlet within the context of a predefined biosphere and a predefined critical group. A dose of 0.25 mSv/year at most in a normal situation is retained by Andra.

The choice was made of the same constraint of 0.25 mSv/year for the repository's operating and closure situations because it refers more broadly to the notion of equity between the generations: we do not accept for future generations detriments which would not be accepted for present-day populations.

For situations considered as altered, the calculated impact is assessed according to the likelihood of the situation, the chronic or timely character of the exposures, and the degree of pessimism of the calculation assumptions.

In that frame, the biosphere constitutes the last step in modelling the transfer of radionuclides and chemical toxins towards "human beings" and to further determine their impact. Various links in the food chain are considered for that purpose. The biosphere is a common topic in the different safety cases addressed by Andra whether they refer to existing surface waste disposal facilities or future projects.

However, according to the safety approach of Andra, no safety function is given to the biosphere. In the geosphere, before radionuclides may reach the biosphere, repository's intrinsic performances are assessed through well-defined and described chemical and physical processes and related scenarios. Other indicators than dose, and directly related to the behavior of the repository components and radionuclides are used, thus avoiding any assumptions on the surface environment and the biosphere. In particular, determining radionuclide concentration flows at relevant emplacements in the geological repository allows refining the judgment on safety and overcoming some of the uncertainties. Different situations or different design provisions can thus be compared to check the most suitable with respect to the limitation of the radionuclide transfers. As illustration the activity flow at each of the repository components, and the concentration distributions of dissolved materials in the host rock and in surrounding formations are indicators used by Andra.

In addition, the safety case of the repository differs from« conventional » nuclear facility safety case by the few following general aspects:

- The necessity of approaching in a coordinated way the different life phases of the repository (i.e. operation, and post-closure) ;
- The consideration of timescales which extend beyond human experience ;
- The strong relationship between technical design, scientific knowledge and safety assessment ;
- The key importance given to uncertainty management especially for the post-closure phase.

This peculiar safety case requires calling on many disciplines (mining and nuclear engineering, earth sciences, material sciences, safety) and implementing specific methods of analysis.

The paper will describe in detail the protection objectives, the different time frames of the life of the disposal facility and how the safety approach deals with the peculiarity of the geological disposal. It will also present the place of the biosphere.

NRC Regulations for Geological Disposal of Radioactive Wastes

T. McCartin

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Abstract- The U.S. Nuclear Regulatory Commission (NRC), over the past 15 years, has made significant revisions to its regulations for geological disposal of high-level radioactive waste to improve effectiveness and efficiency. NRC regulations for geological disposal address both the operational period, when waste is being emplaced and activities are monitored, and the post-closure period (i.e., the time period after the facility is permanently closed). The regulations provide criteria for performing calculations of potential radiological exposures for comparison with dose limits as well as other criteria for limiting the potential for exposures (e.g., requirements for records, access controls, monitoring, criticality controls, testing, alarms, performance confirmation, multiple barriers). Consideration is also given for evaluating the effects of inadvertent intrusion into the geologic repository after it has been permanently closed. NRC regulations for geological disposal implement health-based, safety objectives that are fully protective of public health and safety, and the environment, and are consistent with national and international recommendations for radiation protection.

Report of the ICRP TG 80 “Radiological Protection in Geological Disposal of Long-lived Solid Radioactive Waste”

W. Weiss

ICRP Committee 4
Federal Office for Radiation Protection, Germany

Abstract: The report updates and consolidates previous recommendations of ICRP related to solid waste disposal (Publications 46, 77, 81). The recommendations given in this report apply specifically to geological disposal of long-lived solid radioactive waste. The report explains how the 2007 ICRP System of Radiological Protection described in ICRP Publication 103 can be applied in the context of the geological disposal of long-lived solid radioactive waste. The report is written as a self standing document.

The 2007 ICRP System of Radiological Protection maintains the Commission’s three fundamental principles of radiological protection namely justification, optimisation, and the application of dose limits. The Recommendations evolve from the previous process-based protection approach using practices and interventions by moving to an approach based on the exposure situation. They maintain the Commission’s current individual dose limits for effective dose and equivalent dose from all regulated sources in planned exposure situations. They re-enforce the principle of the optimisation of radiological protection. The Recommendations also include an approach for developing a framework to demonstrate radiological protection of the environment.

This report describes the different stages in the lifetime of a geological disposal facility and addresses the application of relevant radiological protection principles for each stage depending on the various exposure situations that can be encountered. In particular, the crucial factor that influences the application of the protection system over the different phases in the lifetime of a disposal facility is the level of oversight that is present. The level of oversight affects the capability to reduce or avoid exposures. Three main timeframes have to be considered for the purpose of radiological protection: time of direct oversight when the disposal facility is being implemented and active oversight is taking place; time of indirect oversight when the disposal facility is sealed and indirect oversight is being exercised to provide additional assurance on behalf of the society; time of no oversight when oversight is no longer exercised because memory is lost.

Stakeholder Involvement with Development and Implementation of ICRP Recommendations: The NEA Experience

T. Lazo

OECD Nuclear Energy Agency

Abstract - The OECD Nuclear Energy Agency, through its Committee on Radiation Protection and Public Health (CRPPH), has for many years been interested in the recommendations of the ICRP. Being a committee of radiation protection regulatory authorities and radiation protection experts from national technical service organisations, the CRPPH membership is intimately involved in the development and implementation of national radiological protection regulations. As such, the CRPPH has remained interested in interacting with the ICRP regarding the development of any new recommendations, as well as regarding their interpretation for practical situations. For this reason, the CRPPH very willingly engaged actively with the ICRP for the development of the Commission's new general recommendations, Publication 103.

This interaction began with the publication of Roger Clarke's article, Control of low-level radiation exposure: time for a change? The Committee contacted Prof. Clarke, then the ICRP Chair, and began a 7-year interaction with the ICRP, including:

- the development of CRPPH views on how the system should evolve, resulting in 13 CRPPH expert group reports;
- the organisation and assessment of 7 international meetings to discuss various ICRP draft versions, and to discuss key topics (e.g. radiological protection of the environment);
- the detailed assessment of 4 draft versions of what eventually became ICRP Publication 103.

This effort mobilised a large fraction of the resources of the CRPPH for this time, but was largely seen as a win-win situation. The CRPPH membership actively engaged with the ICRP, providing views and feedback as to how the new recommendations could best serve the needs of the CRPPH members. As a result of these efforts, the CRPPH membership felt invested in the ICRP recommendations, and when they were finally issued in 2007 felt that they broadly understood and accepted the recommendations.

The CRPPH brought this same engagement enthusiasm to the implementation of the Publication 103 recommendations as codified in the International Basic Safety Standards. The CRPPH membership and Secretariat participated in 63 meetings to develop the 2011 BSS text, and performed 4 detailed international assessments of draft versions. Again, the CRPPH was in a position to enthusiastically recommend to the NEA Steering Committee that the new BSS should be co-sponsored by the NEA. This view was the result of the active participation engaged in by the Committee for the preparation of the new text.

Both of these examples demonstrate the value that the CRPPH sees in active stakeholder engagement as key radiological protection documents are developed, and the value that this engagement brings to the developer of such documents.

The Role of the Radiation Protection Professional

K. R. Kase

President, International Radiation Protection Association

Abstract - The International Radiation Protection Association (IRPA) has a membership of approximately 17,000 individuals who are members of 48 national societies in 61 countries worldwide. As such IRPA is the voice of the radiation protection professional. IRPA recognizes that the International Commission on

Radiation Protection (ICRP) is the international body to determine policy and to make recommendations for protection against ionizing radiation and IRPA is in position to participate in and to facilitate the implementation of those recommendations. A significant goal of IRPA is to be recognized by its members and stakeholders as the international voice of the radiation protection profession. The 13th International Congress of IRPA will be held in Glasgow in May 2012 under the theme of Living with Radiation – Engaging with Society. This focus will provide significant opportunities for discussion of ICRP recommendations and standards relevant to protection of workers, the public and the environment, and their effective implementation. As an international organization of radiation protection professionals, IRPA provides the forum for discussion of issues related to effective development and implementation of radiation protection recommendations. This presentation will discuss elements of the outcome of IRPA 12, Focus on the Future, the objectives of the IRPA Strategic Plan 2010 – 2020, Criteria and priorities for IRPA Engagement with International Organizations, the current IRPA initiatives in the areas of Radiation Protection Culture and Certification/Qualification of Radiation Protection Experts, the planning for the IRPA13, and comments on current ICRP recommendations and suggestions about IRPA participation in their implementation.

Revision of the International Basic Safety Standards: Building on ICRP's Philosophy

R. Czarwinski

International Atomic Energy Agency, P.O. Box 100, Wagramer Strasse 5, 1400 Vienna, Austria

Abstract- The International Atomic Energy Agency (IAEA) issues Basic Safety Standards (BSS) for protection against ionizing radiation since nearly 50 years. The responsibility of the IAEA lies inter alia in the translation of scientific evidence concerning health effects and radiation protection into regulatory language to ensure a safe application of ionizing radiation worldwide in areas like medicine, research and industry. The development of Safety Standards takes account of the findings of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and of the Recommendations of the International Commission on Radiological Protection (ICRP). The first BSS published in 1962 was based on ICRP "Publication 1" from 1958. Meanwhile the fifth revised International Basic Safety Standards on radiation protection was approved by the Board of Governors on 12th September 2011 based on recommendations of ICRP 103. This revision of the BSS was based on information derived from the experience of States in applying the requirements of the previous Safety Standards and from experience in many States in the use of radiation and nuclear techniques. The revision was done in close cooperation with international organizations as European Commission (EC), the Food and Agriculture Organization of the United Nations (FAO), the International Labour Organization (ILO), the Nuclear Energy Agency of the Organization for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO), the United Nations Environment Programme (UNEP) and the World Health Organization (WHO).

The implementation of the safety requirements of the Basic Safety Standards into national legislations is a necessary step to ensure a harmonized radiation protection globally.

The presentation gives a brief view on the history, the dovetailing of relevant international organizations in the development and revision of the Basic Safety Standards and addresses requirements/topics which demand particular reflection and consideration e.g. medical exposure, non-medical exposure, radon and dose limits. Necessary future cooperation will be raised.

Past Experience and Future Plan in Korea

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Abstract-Korea has now 21 units of NPPs in operation and 5 other units under construction. Korea is also planning to construct 6 more units until 2020. As of the end of 2010, the installed capacity of nuclear power is about 18 GW, sharing about 25% of total installed capacity and presenting about 34% of total electricity generation in Korea. We have PWR & PHWR fuel fabrication facilities, one research reactor, one very small education purpose reactor and a repository facility under construction. As of the end of 2010, there are about 4,400 registered and licensed users, among which more than 60 % are industrial firms. The number of RI and RG users has been continuously increased during the last decade for more than 10% and it is still increasing. Since ICRP published its 1990 recommendations as ICRP 60, many different numerical restrictions had been also published in a number of publications. Coming into the 21st century, ICRP decided to introduce the new paradigm of radiation protection and to revise its recommendations in a more coherent and comprehensible manner. After long process of opinion hearing involving wide spectrum of experts and organizations worldwide, ICRP finally published its 2007 recommendations as ICRP 103. This paper describes the Korean experience of the implementation of the ICRP 103 into Korean regulations. Based on the previous experience of the introduction of ICRP 60 recommendations, Korea has been conducting a five year research project. Now, we are in the final stage of the fifth year. And the first draft of national laws and regulations, which incorporates the ICRP 103 and new IAEA BSS, were published and opinion hearing from the operators of nuclear installations were made and the feasibility study on the applicability of new requirements has been in progress. The final draft of the revision of the rules and regulations is scheduled to be published until the end of February 2012.

We have identified five requirements to be implemented into our rules and regulations. Namely, they are, first, set up of dose constraints and reference level, and change in the tissue and radiation weighting factors, practical application of the exclusion and exemption principles, active participation of the stakeholders, and finally change from process-based system to situation-based system. The paper describes how each of these requirements is reviewed and introduced into Korean rules and regulations. As a provisional conclusion, in general, the impact of the ICRP 103 and new IAEA BSS on our regulations does not appear to be as significant as the one that was resulted from the introduction of ICRP 60 recommendations in about ten years ago. Nevertheless, the impact of the ICRP 103 and new IAEA BSS introduction is expected to be significant, because Korean nuclear industries has grown significantly during the last two decades.

Therefore, we will continue to do the deliberate review and analysis for the proper introduction of the ICRP 103 & new IAEA BSS, so that we can minimize the possible adverse impact on the further development of Korean nuclear industries.

U.S. NRC Discussion of Options to Revise Radiation Protection Recommendations

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Abstract - The Nuclear Regulatory Commission (NRC) is continuing the process of engaging stakeholders on issues associated with possible changes to the radiation protection regulations contained in 10 CFR Part 20, and other parts of the NRC regulations, to increase alignment with international recommendations. The Commission is particularly seeking to explore implications, as appropriate and where scientifically justified, of greater alignment with ICRP Publication 103. Other information from national and international sources is also being considered. Given that the NRC regulations provide adequate protection, the discussion has been focusing on discerning the benefits and burdens associated with revising the radiation protection regulatory framework. The NRC staff, through three Federal Register Notices, has officially solicited comments on a series of key issues, and has conducted a series of facilitated workshops to encourage feedback from a wide range of stakeholders. The issues include the use of updated scientific methodologies and terminology, the occupational dose limits, and the use of the concepts of constraints in optimization. The NRC staff is to provide a policy paper with recommendations to the Commission in April, 2012.

Lung Cancer Risk from Radon Exposure: Contribution of Recently Published Uranium Miners Studies

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Abstract- A review and analysis of lung cancer risks linked to radon exposures was performed by Task Group 64 of ICRP committee 1 and will be published in the near future. It was based mainly on recently published epidemiological studies of uranium miners with relatively low annual exposures to radon and its decay products. A recent European research project called Alpha-Risk made it possible to build a large database regrouping cohorts of Czech, French and German uranium miners and to perform a joint analysis. The estimated excess relative risk of lung cancer per unit of exposure from this study takes into account the influence of chronic exposure over more than 10 years, the attained age or age at exposure as well as possible interactions between radon inhalation and tobacco consumption.
In parallel to this European research program, UNSCEAR and WHO reconsidered their position with regard to radon risk assessment, based on results from both uranium miners studies and a large number of case-control studies that focused on lung cancer risk linked to domestic radon.
Lifetime risk calculations performed by ICRP are mainly based on results from occupational exposure. Task Group 64 members compared their calculations with those observed in domestic exposures studies, obtaining good agreement when making appropriate comparisons considering: : same sex, same attained age, identical scenario and period of exposure and same level of annual exposure. On the basis of ICRP publication 103 reference lung cancer rates, averaged over males and females and over Euro-American and Asian populations, the calculated life time excess absolute risk (LEAR) from radon exposure was close to 14 x 10^{-5} per h mJ m^{-3} (5 x 10^{-4} per WLM). This estimate is about twice that calculated in ICRP Publication 65. A sensitivity analysis concluded that using Euro-American male lung cancer rates would lead to an estimated LEAR of about 20 x 10^{-5} per h mJ m^{-3} (7 x 10^{-4} per WLM). This difference is due to higher background lung cancer rates among Euro-American males. In contrast, using lower background rates such as those of females or non smokers would lead to a lower estimated LEAR per unit exposure.

Radon Dosimetry

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Abstract- Effective dose from the inhalation of radon and its alpha-emitting progeny has been calculated using "epidemiological" and "dosimetric" approaches. Currently, ICRP uses an epidemiological approach in which the risk of lung cancer per unit radon exposure is compared with total detriment per unit effective dose. Hence, values of effective dose per unit radon exposure are obtained and referred to as the dose conversion convention. However, ICRP now proposes that the same approach be applied to intakes of radon and its progeny as that applied to all other radionuclides, calculating effective dose using reference biokinetic and dosimetric models, and radiation and tissue weighting factors. Effective dose coefficients

will be given for different reference conditions of exposure, taking into account factors including inhaled aerosol characteristics and disequilibrium between radon and its progeny. In this presentation, dosimetric calculations of effective dose will be explained and results compared with values obtained using the dose conversion convention. Implications for the setting of reference levels will be briefly discussed. The use of effective dose for protection purposes will be contrasted with the estimation of risk to individuals, including smokers and non-smokers.

Radon and the System of Radiological Protection

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Abstract- The Commission is updating its recommendations on protection against radon exposure according to its new general recommendations (Pub 103 and Pub 101 on optimisation). The future publication will remain in line with the previous Pub 65 dedicated to radon. It will also take into account the future Pub 115 on the lung cancer risk from radon and progeny. Radon exposure arises in dwellings, workplaces and mixed-use buildings. Because the most part of the risk is due to exposure at home, it should be addressed mainly in a public health perspective. The approach developed is integrated (focussed as far as possible on the management of the building whatever its occupants), graded (according to responsibilities, especially in workplaces) and ambitious (aiming at reduce both the highest exposures and the overall risk). The recommended strategy, implemented through a national action plan, is mainly based on the optimisation of the protection below a reference level, combining prevention and mitigation. In workplaces, the exposure is regarded as an occupational exposure according to either a quantitative criterion (reference level) or a qualitative criterion (positive list of radon prone work activities). The approach is expected be applicable in all existing exposure situations.

Industry Views on ICRP Radon Statement

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Abstract- In 2009 the ICRP issued a statement on radon which stated the dose conversion factor for radon progeny would likely double and that the calculation of risk from radon should move to a dosimetric approach, rather than the long standing epidemiological one. Through the World Nuclear Association, whose members represent over 90% of the world's uranium production, industry has been examining this issue with a goal of offering our expertise and knowledge to assist with the practical implementation of these evolutionary changes to evaluating the risk from radon progeny. Industry supports the continuing use of the most current epidemiological data as a basis for risk calculation, but believes that further examination of these results is needed to better understand the level of conservatism in the potential epidemiological-based risk models. With regard to the adoption of the dosimetric approach, industry believes that further work is needed before this is a practical option. In particular, this work should include a clear demonstration of the validation of the dosimetric model that includes how smoking is handled, the establishment of a practical measurement protocol, and the collection of relevant data for modern workplaces. Industry is actively working to address the latter two items.

Symposium Summary and Conclusions

Radiological Protection of the Environment

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Abstract- The development of a systematic approach to protection of the environment has required a number of basic steps to be taken, including a discussion of what objectives could reasonably be set, together with an examination of how existing knowledge could best be used in order to achieve them. It has required bold decisions to be made, new modelling to be undertaken, and new data sets to be compiled. Equally challenging, however, has been the need to fold the entire subject area into an expanded system originally developed for the protection of human beings. There are, inevitably, a number of data gaps; and further decisions need to be made. But the priority now is to examine how this approach to protection of the environment can be used in practice. With an intensifying world-wide debate about the environmental merits of different forms of energy production, it would seem imperative that the various practices involved in the nuclear fuel cycle are able to demonstrate, clearly and independently, their own actual or potential impact on the environment. The ICRP now has the basic means for such evaluations to be made, and further developments in this system will reflect the experience of its practical application.

Symposium Registrees

(As of October 1st 2011)

Bold **ICRP Main Commission Members and Emeritus Members, Committee Members, and Observers**

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