Occupational Radiation Protection

Enhancing the Protection of Workers — Gaps, Challenges and Developments

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OCCUPATIONAL RADIATION PROTECTION

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FOREWORD

In 2002 the IAEA organized the first International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation, which was hosted by the Government of Switzerland and jointly convened by the International Labour Organization (ILO) in Geneva, Switzerland. The conference, which addressed issues in radiation protection of workers, resulted in an international action plan on occupational radiation protection that has accelerated and guided international efforts to improve occupational radiation protection worldwide. While the conference provided very broad international input on the status of occupational radiation protection at the time, much work remains to be done, specifically in the areas of medicine, naturally occurring radioactive material and the nuclear industry in general. In recent years new developments have brought additional challenges that need to be addressed by the international community.

The publication of IAEA Safety Standards Series No. GSR Part 3, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, was an important development in the area of radiation protection and presents regulators, operators and workers with new challenges in implementing the occupational radiation protection requirements in relation to different exposure situations. A particularly important issue to be addressed relates to the reduction of the dose limit for the lens of the eye.

The Fukushima Daiichi nuclear accident highlighted various challenges in terms of approaches, measures and actions for radiation protection of workers in emergency situations. For example, better monitoring programmes — in particular for those workers receiving high doses and those subject to internal exposures — are necessary to reduce uncertainties in exposure assessment. Health surveillance for emergency workers exposed to high doses also needs further consideration.

In 2014 a second international conference on this topic, the International Conference on Occupational Radiation Protection: Enhancing the Protection of Workers — Gaps, Challenges and Developments, aimed to exchange information and experience in the field of occupational radiation protection; review advances, challenges and opportunities since the previous conference; identify areas for future improvement; and formulate conclusions and offer recommendations. The conference took place in Vienna and was organized by the IAEA and co-sponsored by the ILO in cooperation with 15 international organizations. The conference provided an important opportunity to review the developments that had taken place since the first conference in 2002 and to exchange information and experience in the field of occupational radiation protection.

This publication includes a summary of the conference, the opening addresses and invited papers, the session chair's report, as well as the conclusions and deliberations of the meeting. The supplementary files, available on-line, contain the contributed papers and respective posters.

An important outcome of the conference was the identification of the nine key areas for occupational radiation protection, known as the Occupational Radiation Protection Call-for-Action. The nine key areas aim to (i) implement the existing international safety standards to improve occupational protection of workers; (ii) develop and implement new international guidance; (iii) strengthen assistance to Member States with less developed programmes for occupational radiation protection; (iv) promote the exchange of operating experience; (v) increase training and education in occupational radiation protection; (vi) improve safety culture among workers exposed to ionizing radiation; (vii) develop young professionals in the area of radiation protection; (viii) convene an appropriate international forum to exchange additional information; and (ix) apply the graded approach in protecting workers against exposures to elevated levels of naturally occurring radiation or radioactive materials.

The IAEA officer responsible for this publication was J. Ma of the Division of Radiation, Transport and Waste Safety.

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CONTENTS

SUMMARY 1

OPENING SESSION 23

Opening Address 25
Y. Amano
Opening Address 27
D. Flory
Opening Address 31
N. Leppink
Opening Address 35
M.F. Weber
Past and Present Perspectives in Occupational Radiation Protection 37
K. Nakamura
Challenges on Occupational Radiation Protection in Nuclear Industry 41
G. Abela

BRIEFING SESSION: ACTIVITIES IN OCCUPATIONAL RADIATION PROTECTION AND MAIN CHALLENGES

An Overview of the IAEA Activities on Occupational Radiation Protection 49
P. Hahn
ILO Activities on Occupational Radiation Protection 55
S.Niu
A Collective Perspective 61
K. Shimomura
Who Activities related to Occupational Radiation Protection 64
M. Perez

TOPICAL SESSION 1: INTERNATIONAL RECOMMENDATIONS AND STANDARDS ON OCCUPATIONAL RADIATION PROTECTION: RECENT CHANGES AND CHALLENGES IN THEIR PRACTICAL IMPLEMENTATION

Occupational Radiation Protection — Stability and Challenges in View of the IAEA Basic Safety Standards 69
M. Pinak
The New EURATOM Basic Safety Standards Directive 75
S. Mundigl
Revision of the International Guidance on Occupational Radiation Protection 77
P. P. Haridasan
ICRP System of Protection — Present and Future 85
D. A. Cool
Rapporteur Summary of Contributed Papers Topical Session 1 93
T. Zodiates
Chairs' Summary of Topical Session 1 95

TOPICAL SESSION 2: DOSE ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURES

Radiation Monitoring and Dose Assessment — Key Requirements for the Implementation of the Principles of Limitation and Optimization in Occupational Exposure 99
H.G. Menzel
The Status and Challenges of External Dosimetry 101
F. Vanhavere

The Status and Challenges of Internal Dosimetry (Technical Aspects) 109
M. A. Lopez Ponte
Revision of ISO 15382 — Answers to the Challenges of Monitoring Doses to the Lens of the Eye.. 115
F. Queinnec, F. Vanhavere
Rapporteur Summary of Contributed Papers Topical Session 2....................................... 119
S. Mundigl
Chairs' Summary of Topical Session 2.. 121

TOPICAL SESSION 3: RADIATION EFFECTS AND HEALTH RISKS FROM RADIATION EXPOSURE AT THE WORKPLACES

Radiation Effects and Health Risks from Radiation Exposure at the Workplaces................ 123
W. Müller
Scientific and Epidemiological Background for Radiation Risk of the Lens of the Eye........ 127
N. J. Kleiman
Evidence of Cardiovascular Disease Risk in the Workplace — A Review.......................... 133
R. Wakeford
Approaches for Estimating Probability of Causation for Compensation Purposes................ 139
H. Zeeb
Rapporteur Summary of Contributed Papers Topical Session 3....................................... 143
M. Perez
Chairs' Summary of Topical Session 3.. 147

TOPICAL SESSION 4: DOSE RECORD MANAGEMENT OF OCCUPATIONAL RADIATION EXPOSURES

Issues in the Management of Spanish National Dose Registry... 151
M.L. Tormo
UNSCEAR Requirements for Occupational Dose Data.. 157
D.R. Melo
Individual Monitoring and Occupational Dose Record Management in China — History, Current Status and Perspectives... 163
H. Wang, Q. Sun
Esorex — A European Platform for Occupational Radiation Exposures............................ 171
A. Rannou, J. Feuardent, P. Scanff, E. Vial
Occupational Dose Record Management in Canada.. 173
M. Tabra, J. Chen, D. Quayle, B. Ahier
Rapporteur Summary of Contributed Papers Topical Session 4....................................... 177
F. Shannoun
Chairs' Summary of Topical Session 4.. 181

TOPICAL SESSION 5: OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL RESEARCH AND EDUCATION FACILITIES

Occupational Radiation Protection in Industrial Radiography — A Review and Recommendations.. 183
R. Van Sonsbeek
Issues in Occupational Radiation Protection in Industrial Radiography — A Regulator View.. 189
A. Al Shehhi

Training and Education Requirments for Occupational Radiation Protection in Industrial Radiography.......... 193
C. Kaps, A. Steege, B. Sölter
Occupational Radiation Protection at Accelerator Facilities — Challenges.......... 199
G. Haridas, T. Bandyopadyay, R. M. Tripathi, D. N. Sharma
Rapporteur Summary of Contributed Papers Topical Session 5.......... 205
M. R. Gaunt
Chairs' Summary of Topical Session 5.......... 209

TOPICAL SESSION 6: OCCUPATIONAL RADIATION PROTECTION IN EMERGENCIES AND EXISTING (POST-ACCIDENT) EXPOSURE SITUATIONS

Lessons Learned: Radiation Protection for Emergency Response and Remediation/ Decontamination Work Involved in TEPCO Fukushima Daiichi NPP Accident.......... 211
S. Yasui
Comparison of Occupational Radiation Protection Following the Chernobyl and Fukushima Accidents.......... 219
M. N. Savkin
The Internal and External Dosimetry Challenges from the Past Experience — Fukushima Daiichi Accident.......... 225
T. Suzuki
ISOE Expert Group — Occupational Radiation Protection in Severe Accident Management 231
E. P. Anderson
Rapporteur Summary of Contributed Papers Topical Session 6.......... 235
S. Nestoroska Madjunarova
Chairs' Summary of Topical Session 6.......... 239

TOPICAL SESSION 7: OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO NATURALLY OCCURRING RADIOACTIVE MATERIALS AND COSMIC RAYS

Challenges in Implementing the Change in Regulations in the NORM Industry.......... 243
R. García-Tenorio
Practical Experience in Implementing Occupational Radiation Protection and Training in the Oil and Gas Industry.......... 247
L.T.C. Neder, L.E. Matta, M.R.F.V. Alves
Regulatory Status and Challenges in NORM Industries in China — Coal and Rare Earth Mining.......... 251
C. Ma
Air Crew Exposure to Cosmic Rays — Challenges and Management.......... 257
G. Frasch
Rapporteur Summary of Contributed Papers Topical Session 7.......... 263
L.E. Matta
Chairs' Summary of Topical Session 7.......... 265

TOPICAL SESSION 8: OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO RADON

Overview of Occupational Radon Exposure — Past, Present and Future.......... 267
D. B. Chambers
Challenges and Implementation from a Regulatory Perspective — South Africa Special Case Mines.......... 273
W. J. Speelman
Practical Implementation of Anticipated Radon Dosimetry Changes in the Mining Industry. 279
G. C. Mason

Rapporteur Summary of Contributed Papers Topical Session 8 285
F. Harris
Chairs' Summary of Topical Session 8 287

TOPICAL SESSION 9: OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

Fostering Radiation Safety Culture — Occupational Radiation Protection in Healthcare 289
J. Malone, U. O. Connor
Improving Optimization in Occupational Radiation Protection in Medicine 293
K. H. Ng
Education and Training of Health Professionals in Occupational Radiation Protection 301
J. Damilakis
Radiation Protection of the Staff in Interventional Procedures 305
P. Ortiz López
Rapporteur Summary of Contributed Papers Topical Session 9 315
S. Fennell
Chairs' Summary of Topical Session 9 325

TOPICAL SESSION 10: OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR/ FUEL CYCLE FACILITIES

Occupational Radiological Protection Principles and Criteria for Designing New Nuclear Power Plants 327
E. Gaillard-Lecanu
Practical Challenges in Ongoing NPP Decommissioning 329
J. Kaulard, H. B. Okyar
Radiological Protection at a Reprocessing Plant 335
J. W. Bishop, Sellafield
Future Nuclear Power Plants in Embarking Countries: The Challenge of Preparing for Occupational Radiation Protection 341
H. Alkatheeri, S. Bilal
Rapporteur Summary of Contributed Papers Topical Session 10 347
H. B. Okyar
Chairs' Summary of Topical Session 10 351

TOPICAL SESSION 11: EDUCATION AND TRAINING IN OCCUPATIONAL RADIATION PROTECTION

The Status of Available Radiation Protection Training Through the IAEA and the Support IAEA Provides to Member States — Developing an Education and Training Strategy for the Country 353
A. Luciani, J. Wheatley
Nuclear Regulatory Agency — 30 Years Building Competencies in Radiological Protection in Latin America — Focus on Occupational Radiation Protection 361
V. Lucía, N. Rubén
Achievements and Challenges in Radiation Protection Education and Training Tanzania's Perspective 367
W. E. Muhogora, S. Yusuph, S.L.C. Mdoe, A. Muhulo
The Role of Professional Societies in Promoting Radiation Protection Education and Training 373
E. Gallego

Learning from Experience and Sharing Lessons Learned — The Role of Networks............ 379
C. Lefaure
Rapporteur Summary of Contributed Papers Topical Session 11 383
A. M. Rojo
Chairs' Summary of Topical Session 11 391

TOPICAL SESSION 12: SAFETY CULTURE

IRPA Guiding Principles on Radiation Protection Culture Drawn Up by RP Professionals for the Benefit of RP Professionals... 395
A. Le Guen
Developments in Safety Culture — Views by the World Nuclear Association and the International System of Occupational Exposure 399
W. Harris
Chairs' Summary of Topical Session 12 405

ROUND TABLE SESSION 1: HEALTH RISK MANAGEMENT

Health Surveillance for Workers Occupationally Exposed to Radiation — Ethical and Technical Guiding Principles 407
S. Niu
WHO's Views on Health Examinations in Different Workplaces 413
M. Perez
Ethical and Technical Guiding Principles on Health Surveillance for Workers Occupationally Exposed to Radiation — Point of View From a Ministry of Health......... 417
O. Luxenburg
Chair's Summary of Round Table 1 419

ROUND TABLE SESSION 2: THE APPLICATION AND INTERPRETATION OF INTERNATIONAL STANDARDS IN EMERGENCY PREPAREDNESS AND RESPONSE

Protection of Emergency Workers and Helpers in Recent Developments in International Standards for Emergency Preparedness and Response 421
S. Nestoroska Madjunarova, E. Buglova, T. Mckenn, V. Kutkov
Emergency Dose Control for Workers at the Fukushima Daiichi Nuclear Power Station Accident 429
A. Suzuki
Temporary Increase in the Emergency Exposure Dose Limit in Response to the TEPCO Fukushima Daiichi NPP Accident.. 433
S. Yasui
Occupational Radiological Protection — The ICRP Perspective Taking into Account Lessons from the Fukushima Daiichi Accident... 437
C. H. Clement
Chair's Summary of Round Table 2.. 441

ROUND TABLE SESSION 3: OCCUPATIONAL RADIATION PROTECTION IN MEDICINE – THE WAY FORWARD

A Technologist's Perspective.. 443
D. Newman
A Medical Physicist's Perspective... 449
M. C. Cantone
A Regulator's Perspective... 453
R. Hernández
A Manufacturer's Perspective... 457
M. Baelen

The Perspective of the Medical Professional Associations.. 459
P. Vock, L. Lau
Chair's Summary of Round Table 3.. 461

ROUND TABLE SESSION 4: CHALLENGES IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION

Challenges in Implementing Occuptional Radiation Protection in Africa.......................... 463
F.A. Ollite
Challenges in Implementing Occupational Radiation Protection in Asia........................... 467
K. Sakai
Challenges in Implementing Occupational Radiation Protection in Latin America.............. 469
L.E. Matta
Challenges in Implementing Occupational Radiation Protection in Central Europe 473
K. Petrova
Technical Cooperation Programme and the Occupational Radiation Protection Appraisal Service... 477
R. Cruz Suárez, J. Ma
Chair's Summary of Round Table 4.. 481

YOUNG PROFESSIONALS ROUND TABLE.. 483

CLOSING SESSION.. 485

President's Summary of the Conference.. 487
M. Weber
Closing Address 491
P.S. Hahn

ANNEX: SUPPLEMENTARY FILES...493

CHAIRPERSONS OF SESSIONS.. 495

LIST OF PARTICIPANTS... 499

SUMMARY

BACKGROUND OF THE CONFERENCE

Objectives

This symposium, the second in a series of symposia on occupational radiation protection, provided an important opportunity to review recent technical and regulatory developments concerning occupational exposure to ionizing radiation in all facilities and activities. The symposium brought together experts from a wide range of countries and international organizations to report on and discuss the progress made in identifying, quantifying and managing the radiological risks associated with workplaces. The revision of international basic safety standards which was completed during the period since the last symposium in 2002 provided an important backdrop to the presentations and discussion.

International aspects

The first International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation, was held in Geneva, Switzerland, from 26 to 30 August 2002. It was hosted by the Government of Switzerland and organized by the International Atomic Energy Agency (IAEA) and was convened jointly with the International Labour Organization (ILO). The conference was co-sponsored by the European Commission (EC) and held in cooperation with the World Health Organization (WHO), the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and other international organizations.

The Geneva Conference was structured so as to obtain the views of stakeholders- i.e., regulators, employers, workers and radiation protection professionals. It was attended by 324 participants from 70 countries and 13 organizations.

The Geneva Conference was the first international conference covering the whole area of occupational radiation protection. A number of specific recommendations emerged from the Conference, which noted that, in general terms, occupational radiation protection over the past few decades has been a success story for the international radiation protection community. Consistently improving trends are found in many key performance indicators, but the picture is not so clear or encouraging for exposures in medicine and industry, nor for exposures to natural sources, especially in the mining of ores other than uranium. This is important, as these are the principal types of exposure encountered globally.

The recommendations and conclusions from the Geneva Conference resulted in an international action plan on occupational radiation protection that has been accelerating and guiding international efforts in improving occupational radiation protection worldwide. While the Geneva conference provided very broad international input on the status of occupational radiation protection at the time, much work remains to be done and specific challenges exist in the areas of medicine, naturally occurring radioactive material (NORM), and the nuclear industry in general. In addition, new developments in recent years have brought with them additional challenges that need to be addressed by the international community.

The overall objective of this action plan is to focus the efforts of the relevant international organizations, in particular the IAEA and ILO, and to assist their Member States in establishing, maintaining and, where necessary, improving programmes for the radiation protection of workers. Implementation of the proposed actions will strengthen international efforts in nine high-priority areas (listed in the action plan) identified as areas of major concern by the Geneva Conference.

This action plan covers important aspects of the control of occupational exposures that have an international dimension, as identified at the Geneva Conference. It therefore deals with matters such as the strengthening of relevant international conventions, the development and maintenance of effective safety infrastructures, the fostering of a safety culture among managements and workers, and the harmonization of international radiation protection requirements that are compatible with other provisions for health and safety at work. The development of education and training and the promotion of information exchange form an important part of the action plan, which proposes joint international efforts in support of decision-making with regard to the attribution of health effects to occupational radiation exposure. The protection of specific groups, including pregnant workers and their embryos and foetuses, is also addressed.

As part of this plan, the occupational radiation protection has been well recognized and established as part of the overall radiation protection system. Scientific information available from UNSCEAR as well as occupational exposure data in the International System of Occupational Exposure (ISOE) reveals positive trends in many key performance indicators such as individual and collective dose reduction, operational experience in radiation protection and application of the optimization principle.

Medical applications of ionizing radiation represent the largest manmade sources of ionizing radiation. The number of occupationally exposed workers in medical facilities has been increasing rapidly over the years, and individual occupational exposure varies widely among those involved in medical care. There are certain medical procedures that might give substantial doses to medical staff.

The extremely extensive distribution of industries involving Naturally Occurring Radioactive Materials, calls for radiation protection in these industries to be addressed and potentially strengthened in terms of identifying the activities giving rise to radiation exposure, and applying a graded approach to control related exposures.

The construction of nuclear power plants in embarking countries, and the introduction of novel designs of nuclear reactors have also given rise to some new issues. For example, there is a need to address comprehensively radiation protection aspects already at the design phase of new NPPs. On the other hand, as many nuclear reactors come to the end of their operating life, decommissioning activities are expected to increase significantly, and this may result in additional challenges for occupational radiation protection. The IAEA is now preparing the material that will address radiation protection in both areas – new NPPs as well as those in a decommissioning phase.

The Fukushima Daiichi nuclear accident has highlighted various challenges in terms of approaches, measures and actions for radiation protection of workers in emergency situations. For example, monitoring programmes, in particular for those workers receiving high doses and those subject to internal exposures, are necessary to reduce uncertainties in exposure assessment. Health surveillance for emergency workers exposed to high doses also needs further consideration.

Exposure of aircrew to cosmic radiation, radon at the workplaces other than mines and protection of pregnant women against radiation continue to be of concern to the affected workers and to some of the national regulatory bodies. The IAEA highlighted in the recently revised BSS the need to address radiation protection of the aircrew.

With increasing mobility worldwide of the workforce, radiation protection of itinerant workers requires further attention. It needs to address issues associated with the qualification, dose monitoring and recording. The IAEA has recently completed the material addressing specifically this category of workers.

INTERNATIONAL RECOMMENDATIONS AND STANDARDS — REGULATORY APPROACHES AND CHALLENGES IN IMPLEMENTATION

Revision of the international standards

A revision of the IAEA Basic Safety Standards (BSS) was completed and the new version of the BSS — the General Safety Requirements GSR Part 3 — was published by the IAEA in 2014. The revised BSS reflected the latest recommendations of the International Commission on Radiological Protection (ICRP). Participants were reminded of how the general approach to radiation protection had changed from one based on the concepts of 'practices' and 'interventions' to one based on three types of exposure situation — planned exposure situations, emergency exposure situations and existing exposure situations. The new radiation protection approach placed greater emphasis on the concept of optimization of protection, regardless of the type of exposure situation. For existing exposure situations, a new approach based on 'reference levels' had been adopted. These reference levels were conceptually different from the 'action levels' used previously and were relevant to natural sources. The requirement for optimization applied below the reference level as well as above it — this was a new development and concern was expressed during the symposium. In addition, greater emphasis was being placed on the graded approach to regulation, although it appeared that this concept was still not universally understood in a consistent manner. Requirements for occupational exposure cover the responsibilities of the regulatory body and the principal parties; worker compliance; information, instructions and training; classification of work areas; monitoring and recording of exposures; assessment of exposures; local rules and personal protective equipment; and special arrangements (pregnant and breast-feeding women, students and apprentices). A challenge is to create the radiation protection (RP) system and establish work cultures so that the prime responsibility for protection and safety remains with the authorized parties and to implement optimization so that "ALARA" is achieved and while legal requirements are still met. The government and the regulatory body should ensure that protection and safety is optimized but the establishment of constraints and the actual optimization should usually be left to, involving the workers, the authorized/principal parties. A timely challenge is managing exposures in emergency situations. To avert large collective doses, save lives or prevent severe deterministic effects, individual doses between 100 - 500 mSv are acceptable. The matter will most certainly merit from further discussions and more guidance.

New recommendations and requirements for exposure to radon were now in place, and these reflected the increased risk coefficient of 8×10^{-10} per $Bq\cdot h\cdot m^{-3}$ (nearly double the previous value) recently recommended by the ICRP. The ICRP was recommending that, for workplaces, the radon level should be optimized to a value below 300 Bq/m^3. If this was not feasible, then the dose criterion of 10 mSv/a should be applied. In workplaces for which the dose from radon continued to exceed 10 mSv/a, the workers should be considered as occupationally exposed and subject to the requirements for planned exposure situations, including a dose limit of 20 mSv/a.

The EURATOM Treaty empowers the European Community to establish legally binding basic safety standards for the protection of the health of workers and the general public – the Euratom Basic Safety Standards Directive (EBSS). The first EBSS of the year 1959 contained detailed requirements on occupational radiation protection. Since then, EBSS was regularly amended reflecting progress in scientific knowledge, technological development and operational experience. This has resulted in a high level of the radiological protection for workers in Europe.

In December 2013, the Council of the European Union adopted the latest revision of EBSS, which updates and consolidates the European radiation protection legislation. It constitutes safety standards covering all relevant radiation sources, including natural, integrates the protection of workers, members of the public, patients and the environment, covers all exposure situations, and harmonizes numerical values with international standards. EBSS offers better worker protection, including emergency workers and workers exposed to enhanced levels of natural radiation sources, such as air crew or workplaces with high radon concentrations. The incorporation of the former Outside Workers Directive into EBSS provides for clear allocation of responsibilities for the protection of a transient worker between the employer and the operator of the controlled area where work is performed. The EU Member States have four years for the transposition and implementation of the new Directive.

A new IAEA safety guide on occupational radiation protection is currently being developed. The guide, prepared jointly by the IAEA and the ILO, covers all exposure situations and all facilities and activities involving ionizing radiation. It advises on the establishment of radiation protection programmes and on monitoring and assessment of doses from external radiation as well as intakes of radioactive material. It includes guidance on the protection of female workers during and after pregnancy, itinerant workers, exposure to natural radiation sources (radon, NORM, cosmic rays), protection of emergency workers, monitoring of the dose to the lens of the eye etc. This comprehensive safety guide will update and supersede five existing guides on occupational radiation protection, assessment of exposures, and the management system for technical services in radiation safety. The draft has been submitted to the Commission on Safety Standards for approval. Publication and application of this safety guide would greatly enhance the protection and safety at workplaces.

The ICRP system of protection is structured to provide a consistent approach to protection against ionizing radiation in all exposure situations (existing, planned, and emergency) through justification of protection actions, and optimization of protection using individual dose criteria to identify individuals that warrant specific attention and modify the distribution of exposures to levels that are as low as reasonably achievable. Dose limits are a specific form of individual dose criteria that may be used by a competent authority to identify values that are legally unacceptable in a specific set of circumstances. Occupational protection can be systematically approached through the assessment of exposures, optimization of protection, and involvement of the stakeholders, particularly the individual workers themselves in a strong radiation protection culture.

Some of the contributed papers indicated that whilst occupational exposures in nuclear power plants have reduced over time, the experience in other areas is mixed. Many challenges remain in the practical application of occupational radiation protection such as:

- Lack of finance and resources;
- Lack of infrastructure;
- Lack of competent staff, in particular Radiation Safety Officers;
- Lack of internal dose assessment;
- Lack of extremity assessment;
- Regulator as a Technical Support Organization (e.g. dosimetry service);
- Nuclear Plants: itinerant workers;
- Mines: ventilation issues / uncertainties in internal dose assessment; and
- Medical: RP awareness is low.

It remains vital to foster a good radiation protection culture. The effective implementation of a protection system requires awareness, dialogue and the engagement of stakeholders. At present, the focus should be on the practical implementation of the standards and assistance to countries with less developed RP programs is important.

DOSE ASSESSMENT

The importance of harmonized units and dose assessment methods to occupational radiation protection was emphasized in the conference. The status and emerging problems with the current system of radiation units, presentations on new developments and challenges in external and internal dosimetry and the measurement of dose to the lens of the eye were among the subjects discussed.

It was pointed out that the use of the protection quantity effective dose had enabled the occupational radiation protection community to apply the optimization and limitation principles in such a way that the average annual effective doses and the annual collective doses in each planned exposure situation have decreased year after year. Operational quantities for external radiation have been introduced 30 years ago and are facing limitations and restrictions in their application at high radiation energies and also due to conceptual difficulties (composition of ICRU sphere, depth in sphere). The dose coefficients for occupational intakes of radionuclides (OIR) following the ICRP 103 recommendations need to be evaluated and published. The radiation weighting factors are still based on few, not always pertinent scientific data (RBE values). An open question is whether the quantity of equivalent tissue dose is suitable at high radiation doses. Currently an ICRU Committee is reviewing the definition of the operational quantities.

There is a worldwide tendency for external monitoring services to establish quality management systems, and for regulatory agencies to require authorization or certification of these services. The most complete quality management system is considered to be that following the guide ISO 17025. The result of additional quality requirements is additional costs to the services, which in turn has led to a reduction in the number of the services and the consequent increase in the number of occupationally exposed workers per service. This trend is likely to continue. As to the measurement uncertainties, improvements in the dose calculation algorithms are always important. Intercomparisons are a key tool to demonstrate compliance with the performance requirements. For Hp(10) from photons, the EURADOS intercomparisons show that the services can measure dose within the trumpet curves. However, these intercomparisons are usually limited to simple radiation fields, with no mixture of photon energies and angles. For extremity dose measurement and for neutron and beta dose measurement the situation is worse and further intercomparison exercises and improvements in the dosimeter design and algorithms should be undertaken. As to the future, a possible narrowing of the performance requirements of the dosimetry service might be proposed. Improvements to neutron personal dosimeters and better response to low-energy beta radiation should be made. Active dosimeters should also become more commonplace in the planned exposure situations. Computational methods for dose calculations will be more used in the future.

The current status of internal dosimetry methods, international standards and guidelines, especially recent ISO standards were discussed in the conference. For harmonization and higher efficiency in measurement it turns out that networking and coordination of research is essential. Notable examples include the EURADOSE initiative, the CURE project, MELODI and OPERA. The next few years in internal dosimetry will see further accreditation of internal dosimetry laboratories and services and the implementation of the newly proposed Occupational Intake of Radionuclides (OIR) publications on biokinetic models to be published by the ICRP. The work on harmonization of methods and new and existing methods will continue, especially in Europe. Main challenges identified in the frame of internal dosimetry are to continue in the improvement of monitoring techniques, dose evaluation and management of people, samples and communication in case of a nuclear or radiological emergency. Further studies should be carried out on the internal dosimetry of medical staff at risk of intake of radionuclides. New tools are being applied for in-vivo monitoring of internal exposures such as Monte Carlo calibration using voxel or NURBS phantoms. Networking and multidisciplinary research projects should continue such as the CURE Project "Concerted Action for an Integrated (biology – dosimetry – epidemiology) Research project on Occupational Uranium Exposure". More realistic biokinetic models for the study of non-cancer effects of internal exposures including radiopharmaceuticals should be developed.

The issue of eye lens dosimetry has received renewed attention due to the lowering of the annual dose limit. A summary was made of the workplaces where the eye lens dose is of importance. The revision process and objectives of standard ISO 15382 "Radiological protection – Procedures for monitoring the dose to the lens of the eye, the skin and the extremities" were described. Photon exposures (8 keV–10 MeV) and electron/positron exposures (60 keV–10 MeV) are taken into account. More services are supplying dosimeters for Hp(3). EURADOS is organizing intercomparison exercises, however further such initiatives are welcomed. Most monitoring is performed with passive dosimeters, but active dosimeters using small silicon detectors may also be used.

The contributed papers identified dosimetry challenges in new medical procedures and techniques, eye lens dosimetry and dosimetry in pulsed fields.

RADIATION EFFECTS AND HEALTH RISKS AT WORKPLACES

An update of knowledge regarding the health risks associated with occupational exposure to ionizing radiation was presented. After a general overview, the issue of effects in the eye lens, and that of the risk of cardiovascular disease were discussed in specific presentations, as were developments in the concepts of probability of causation, and of new computerized methods for its calculation. The points discussed were relevant not only for radiation protection professionals, but also for occupational health professionals not knowledgeable in radiation protection. In fact, for the latter professional group increasing the level of knowledge and awareness of the risk(s) associated with ionizing radiation are highly desirable.

The term “tissue reactions”, are related to death of multiple cells, and manifestly occur after exceeding a dose threshold (in most cases in excess of one gray or more) and their severity are-dose related. In contrast, stochastic effects, initiated by modifications (in particular of the genome) compatible with survival of the cells, can ostensibly occur without threshold, and affect the incidence of disease in an exposed population that increases with increasing dose (the so-called LNT concept, Linear Non-Threshold). Biological arguments existed for models other than LNT, especially at low and very low dose; however, these arguments could not be confirmed, so assumptions had to be made on the model to use for protection purposes. Currently, it was not clear whether cataracts and circulatory diseases were of a deterministic or a stochastic nature or something else. The same issue applied to some radiation effects during pregnancy such as to the induction of malformations during the early preimplantation period of the embryo that had been observed in some mouse strains, or reduction in IQ.

It is challenging to decide whether a specific health effect can be attributed to ionizing radiation exposure. Attribution is possible for deterministic effects after high acute doses, but a stochastic effect in an individual cannot be unequivocally attributed to radiation exposure, because: (a) radiation exposure is not the only possible cause and (b) there are no available specific biomarkers evidencing that radiation was responsible for the observed health effect.

The inference of risk in the low and very low dose range, for which the prediction of future stochastic health effects in a strict scientific sense is very uncertain. Generally, it does not make sense to calculate numbers of cases of death based on the multiplication of low doses or, in particular, very low doses and the number of individuals affected. An exception to this may be when comparing options in certain situations, but it is important to recognize the uncertainties and that the numbers of effects are notional in naturel.

Increased incidence of cataracts was reported in various epidemiological studies, on cohorts such as the atomic bombing survivors, astronauts, clean-up workers after the Chernobyl accident, and radiological technologists and other medical personnel such as those involved in interventional cardiology. Based on the results of the available studies, the ICRP recommended a reduced eye lens limit from 150 mSv to 20 mSv in a year. The rate of progression of radiation-associated lens changes seems slow. While treatment is surgical removal of the cataract, potential visual disability and morbidity resulting from the radiation cataract and/or its treatment may be underappreciated. It is still not clear whether radiation-associated cataracts related to exposure at low doses are stochastic or deterministic in nature. Establishing an accurate dose threshold for radiation cataractogenesis, if any, is considered important for risk assessment and exposure guidelines.

Evidence of cardiovascular disease risk in the workplaces was noted. The conference concluded that, currently, the findings of occupational studies cannot be reliably interpreted because of the lack of a proper understanding of the influence of important background risk factors, and of a broadly accepted radiobiological mechanism. Thus, the findings currently available do not give adequately convincing evidence for any excess risk of circulatory disease in relation to low-level radiation exposure. Currently the ICRP does not include radiation-induced risks of non-cancer somatic diseases, such as circulatory diseases in the exposed individual, at low-level exposures in the framework of radiological protection.

The approaches for estimating probability of causation for compensation purposes were presented. Manifestation of disease (say: a cancer) cannot be unequivocally attributed to a specific cause, such as ionizing radiation. The approaches applied to describe the likelihood that an individual case was actually caused by prior radiation exposure are based on epidemiological and statistical approaches, drawing inferences from large exposed populations to individual cases, using the concept of probability of causation. It was concluded that the concept of probability of causation rested on an epidemiological and statistical basis. Both, for the actual calculation as well as for the interpretation of the data, uncertainty from various sources needs to be properly taken into account when estimating probability of causation for claims cases: new software programmes may be helpful in the estimation.

DOSE RECORD MANAGEMENT

National dose registers provide benefits to workers, employers and regulators. National registers may also be used as indicators for good radiation protection and to monitor the success of optimization. National registers support the requirement for the long-term preservation of worker dose records. They may also be used as indicators for good radiation protection and to monitor the success of optimization. They require a well-defined legislative framework for data sharing, data protection to ensure personal confidentiality, and for measures to ensure long-term preservation of worker doses.

The presentations by Spain, China and Canada, together with the poster by Federation of Bosnia and Herzegovina, highlighted the benefits and challenges of maintaining national dose record management systems. In Spain, the National Dose Register was established by the Nuclear Safety Council (CSN) in 1985. It now contains more than 20 million records covering 332,000 workers and 65,000 facilities. The NDR provides long-term management of worker dose records, with data provided by the dosimetry services from individual TLD monitoring of workers. Since the dose records are health information, personal data protection legislation applies. Access by workers to their own dose records is through the CSN webpage.

China has about 60,000 radiation facilities with more than 300,000 radiation workers. Most of these workers are associated with medical uses of radiation and the nuclear industry. Legislation within China requires individual monitoring of occupational radiation exposure. There are more than 200 individual monitoring providers in China. In 2005, following an IAEA ORPAS mission, the China Register of Radiation Workers (CRRW) was developed under an IAEA CRP activity. The CRRW was officially released in November 2009 and now covers ~90% of workers in hospitals. There are challenges for quality assurance and quality control, particularly for internal contamination, and for the expansion of the CRRW to cover non-uranium miners and aircrew.

The Canadian National Dose Register was established in the mid-1970's by the National Dosimetry Service within Health Canada. It now operates independently from the dosimetry service providers and from the regulatory authority. Canadian legislation requires all licensed dosimetry service providers, nuclear power station operators and uranium mines to provide worker's dose records to the dose register. The NDR now has information on ~870,000 radiation workers (160,000 workers in 2013) across more than 35,000 employers. These presentations demonstrated that good coordination for data collection on occupational exposure is required within a well-defined legislative framework for data sharing and data protection to ensure personal confidentiality, to ensure long-term preservation of worker doses. There are issues with the categorization of workers/work activities, and for the quality assurance of the data as well as certain groups of exposed workers who are not yet monitored (e.g., mines, air crew and some in the medical sector.) Significant action is required at the national level to set up and maintain a national dose registry, both in developed and developing countries.

International cooperation activities to collect and evaluate data on occupational radiation exposure across national boundaries were highlighted. The UNSCEAR presentation highlighted the need to have a robust database that reflects the real picture of the global situation on occupational radiation exposure. UNSCEAR has conducted assessments of global occupational radiation exposure since 1975, based on information from the 194 UN Members States and the published peer-reviewed literature. The surveys include man-made sources of radiation and more recently, exposure to natural sources. The UNSCEAR will be undertaking an updated evaluation with the aim of providing a comprehensive estimate of worldwide occupational dose distributions and trends. UNSCEAR has reiterated the need for a good international coordination and cooperation of all national authorities for data collection on occupational radiation exposure. A questionnaire for the collection of worker data will be sent to the Member States through the national contact points.

The European Commission initiated the European Study on Occupational Exposure (ESOREX) in 1997. A recommendation in 2010 for a sustainable platform has resulted in the establishment of a WEB-based platform in 2014 for exchange of information between EU national dose registers. ESOREX was shown as a good example on how to synergize efforts on a regional level to collect and evaluate data on occupational exposure. National authorities should be encouraged to support UNSCEAR and ESOREX by sharing information on occupational exposure.

INDUSTRIAL, RESEARCH AND EDUCATION FACILITIES

Occupational radiation protection in industrial radiography is relatively mature with a systematic approach involving Radiation Protection Officers, training and qualification following IAEA recommendations. There are occasional accidents, and a need for improvement in harmonization (and recognition) of training, equipment, and communications.

The Industrial Radiography Working Group (WGIR) of the Information System on Occupational Exposure in Medicine, Industry, and Research (ISEMIR) discussed the current status of radiation protection in industrial radiography as determined via a survey that was conducted. The WGIR concluded that considerable improvement is needed in the area of occupational radiation protection in industrial radiography, especially in the area of implementation of optimization of protection. Consequently, the WGIR developed two tools, an international database and a road map, which can be used to assist end-users in improving their radiation protection programs. Various recommendations were given to IAEA for further action to include development of an internationally recognized training standard for safety in industrial radiography operations, encourage adoption of the equipment standard ISO 3999 as a means of international certification, and determine the circumstances and reasons why radiographers do not always use survey meters in order to avoid accidents. The WGIR of the ISEMIR project could play a significant role in the implementation of these actions. The main challenge is achieving broader involvement form the non-destructive testing industry.

A regulator’s perspective on issues in occupational radiation protection in industrial radiography in the United Arab Emirates to manage oversight of service providers that cover dosimetry, calibration, certification, and training services in radiation safety was highlighted, including the need for regulator to be active in outreaching to provide a culture of communication with licensees, gain mutual trust, and enhance the safety culture. Operators, as well as the regulators, face challenges such as industrial radiographers receiving excessive doses, blaming employer, lack of training, lack of safety culture and communication problems.

The French Non-Destructive Testing Confederation in France (COFREND) discussed controlling the risk due to the use of gamma sources for non-destructive testing and the first feedback from the deployment of replacement non-destructive testing techniques. In an effort to reduce the risk associated with industrial radiography, the French Nuclear Safety Authority began working with industrial radiography companies to develop and optimize the best practices during radiographic inspections, and it evaluates replacement techniques to radiographic testing. Utilities undertook a global initiative to reduce the number of gamma exposures associated with non-destructive testing within the last five years (e.g., replacement, limitation of exposures), thereby reducing the risks. Industrial radiography will continue to have an important role in non-destructive testing, because there are situations where radiography was found to be the most appropriate and most efficient type of non-destructive testing technique. For these cases, the use of less powerful x-rays and gamma-ray sources and the implementation of good practices by the operators can highly reduce the risks of radiation exposure.

The German Society for Non-Destructive Testing provided an overview of the training and education requirements for occupational radiation protection in industrial radiography. Every Radiation Protection Officer is liable for his in-plant authority; however, this is found to be challenging for on-site industrial radiography. In Germany, law requires radiation protection training; training is also addressed in international standards. Training in combination with work experience and up-to-date courses is one step towards safe and secure handling of sources and radiation protection. Germany has different training requirements depending on the job position (Radiation Protection Officer for overall direction versus on-site Radiation Protection Officer) and the technique (gamma radiography versus x-ray radiography). Knowledge in radiation protection can be proved by written exams during a course, but work experience is much more difficult to acquire. An option to address this challenge is the certification of non-destructive personnel.

There are growing challenges of occupational radiation protection at accelerator facilities worldwide. Accelerators in terms energy, intensity and technology are growing at a rapid pace, which is driven by the need of industry, research & development in basic and applied science, medicine, agriculture and in many other fields. Due to the technological advancement in the field of accelerators, there are many challenges faced by radiation protection professionals, which are mainly due to the characteristic radiation environment prevailing in such facilities.

Important among them are:

- Dynamic nature of the radiation level due to change in beam loss scenario;
- Lack of systematic data on source term;
- Detection and measurement of high and low energy radiation;
- Underestimation of personal and ambient dose equivalent;
- Radio-frequency (RF) interference; and
- Enforcing regulatory recommendations and radiation protection procedures.

There are areas, such as development of area monitors and survey meters suitable for monitoring high and low energy radiation, pulsed radiation and mixed field, which need to be undertaken by the manufacturers. Substantial research is required to address these issues. Due to the uncertainties in dose estimation prevailing in these peculiar radiation environments, greater importance may be given to engineered, redundant radiation safety systems like various interlocks, shielding (with safety margin), zoning, access control and strict adherence to training of personnel and operational procedures. Also, efforts shall be made in standardizing radiation safety systems for accelerator facilities and evolving a policy for ensuring their effectiveness.

EMERGENCIES

The problems that occurred during emergency work at TEPCO Fukushima Daiichi NPP in 2011 and extracted lessons learned from the experiences in radiation protection and provided guidance regarding preparedness for a similar accident in the future. The operator and authorities faced difficulties in determining how radiation protection systems intended for planned exposure situations should be applied to the existing exposure situation. The problems that had been faced to and lessons learned were aggregated into two groups, which are related to radiation protection and medical care of emergency workers. The following gaps in radiation protection of emergency workers have been underlined by the MHLW during early phase of response to Fukushima accident: Inappropriate monitoring of external exposure, internal exposure, inappropriate dosimeter circulation management and exposure control, inappropriate registration of the emergency workers and training of some groups of emergency workers. Problems in the medical management of emergency workers were also underlined and linked with the loss of the designated hospitals (which were located at the affected territory in vicinity of the Fukushima Daiichi) due to the natural catastrophe produced by the combination of the earthquake and the tsunami. It was stressed that the international guidance documents on emergency preparedness and response issued by the IAEA were an important support to the government and NPP operator to perform necessary measures for radiation protection of emergency workers, particularly taking into account the lack of national regulations for emergency response.

A comparison of occupational radiation protection following the Chernobyl (USSR, 1986) and Fukushima accidents (Japan, 2011) was discussed. The major conclusion of the performed analysis was that transition from planned exposure situation to emergency exposure situation in a case of severe NPP accident is the key problem of radiation protection of emergency workers. The problem rose up during the Chernobyl accident in 1986 and appeared again in 2011 during the Fukushima accident. An important issue highlighted was the ethical dilemma during an emergency for handling the restrictions of exposure of rescuers. Should teleological, consequential, ethical principles be used (namely, ‘mind the ends, which justify the means’)? Or should deontological ethical principles be used (namely, ‘not do unto others what they should not do unto you’)?

The internal and external dosimetry challenges from Fukushima Daiichi accident was also discussed and described situations about radiation protection and dose evaluation concerning the Self Defence Forces, the fire-fighters, the police and TEPCO and contractor’s workers from a practical viewpoint of qualified experts involved in radiation monitoring of emergency workers. Several important operational lessons were learned from personal experience. The major ones are related to the control of internal exposure. It was recognized that the thyroid monitor was not set up in Fukushima Daiichi NPP at all. Whole Body Counter was calibrated only for control of Co-60 and Mn-54 and could not be directly used for monitoring of I-131, Cs-134 and Cs-137 in the event of nuclear emergency. Alternative WBC in NIRS was too sensitive that it was not possible to use it in monitoring of highly internally contaminated emergency workers.

A summary of the activities of the ISOE Expert Group on Occupational Radiation Exposure in Severe Accident Management (EG-SAM) was presented and the objectives were to contribute to occupational exposure management in managing high radiation area worker doses and report the best radiation protection management practices for proper radiation protection job coverage during severe accident response. The conclusions of final report regarding organizational and technical measures for radiation protection of the emergency workers in case of severe radiation emergency are in line with the draft safety requirements in GSR Part 7.

The international standards on emergency preparedness and response provide comprehensive requirements and guidance for protection of emergency workers however, further work is necessary to support their practical implementation. It has been recommended to IAEA and ILO to consider a dedicated meeting on the protection of emergency workers. While a long tradition of occupational health and safety policies exist under the framework of ILO which also covers the current international occupational radiation protection policy, it is not clear how these policies cover emergency workers. This issue requires priority attention and should include ethical considerations that sometime could be competing. Notwithstanding, the key urgent issue remains the implementation of the international requirements and guidance on protection of emergency workers in the national framework for occupational radiation protection. The issue of unclear and competing responsibilities for occupational radiation protection is particularly crucial during emergencies because, as the Fukushima accident demonstrated once again, most of the workers involved are not the traditional ‘nuclear’ workers under the responsibility of the licensee. International undertakings are not fully clear on the responsibilities of governments and regulatory bodies, licensees, undertakers, and registrants, as well as the ultimate main responsible party, the employers. The quantification of radiation exposure during an accident continues to be an issue that requires further attention considering that the radiation protection quantities in normal operations have been defined for low doses.

EXPOSURE TO NATURAL SOURCES

A variety of industrial applications utilize materials of geological origin, and these contain naturally occurring radioactive materials (NORM), either at their original concentration or inadvertently enhanced through industrial processes. Working with NORM can produce occupational radiation exposures, as well as public exposures, i.e., from the use, reuse, and disposal of NORM residues. In recent years, there has been an increasing awareness that such exposures can be significant, and that a graded approach to radiation protection control is required. The challenges involved in implementing regulations in NORM industries were outlined. This traced the evolution of this subject, starting from the 1996 IAEA International Basic Safety Standards, through the series of international NORM conferences, up to the revised IAEA BSS (GSR Part 3) in 2014 and beyond. While there have been many debates (and even confusion) about how to apply a graded approach, it is hoped that the revised BSS will provide much greater clarity on how the system of protection should be applied to NORM. Even so, it was suggested that this leaves scope for misunderstanding or misapplying concepts such as reference levels. It was also noted that there is not yet enough evidence of the practical application of optimization, i.e., a principle that applies to all exposure situations.

Topical presentations were given on occupational radiation protection in the oil and gas industry in Brazil, and the regulatory challenges in China, which has a large number of NORM industries and millions of potentially exposed workers. There were six contributed papers covering metal smelting (Egypt), rare earth production (India), NORM processing industries

(Canada), coal-fired power plants (India), and uranium mining and processing of monazite (Brazil). The main themes to arise from the session were:

The main industries involving occupational radiation exposures from NORM have now been identified and characterized, but there is still a need to implement a graded and proportionate system of control.

Exposures to NORM can contain characteristics of both existing and planned exposure situations, and debates about the most appropriate form of control have caused confusion and delay. However, it is now being understood that graded controls are required for both types of exposure situation.

There is a need to consider the application of optimization in practice. This requires realistic dose estimates for NORM workers using workplace measurements, and not models that often significantly overestimate exposures.

More guidance is required on the derivation and use of dose constraints and reference levels. This should show how these concepts could be applied to NORM industries in practice.

NORM industries are diverse and present a wide range of radiological characteristics. Consequently, an industry-specific approach essential.

More emphasis is still needed on radiation protection awareness in NORM industries, and the training of NORM workers.

The management of NORM residues and waste, including the remediation of contaminated sites, is one of the main challenges, and involves occupational and public exposures. Some NORM residues are produced in extremely large quantities, and there is increasing emphasis on the re-use and recycling of these materials – processes that will also require a graded approach to radiation protection control.

The session included a topical presentation from Germany on air crew exposure to cosmic rays, which generated a lot of discussion. Such exposures can now be well characterized through a knowledge of flight patterns. The results indicate that individual and (especially) collective occupational exposures can be significant. This has been known for some time, but it was noted that there is now a significant upward trend in occupational exposures due to changes in the way the commercial aviation industry operates. The scope for optimizing such exposures has always been limited; however, the presentation indicated that there are protection options in terms of flight planning and operation, and that these are worthy of further examination and an on-going dialogue with the airline industry.

RADON

An overview of the evolution of the history of radiation protection standards to radon and its progeny was presented. It was noted that radon in workplaces varies widely with geology and work practices. With increasing knowledge of radon and its health impacts, regulatory standards and work practices have evolved with time. Data presented showed a decrease in workers' exposures of several orders of magnitude in Canadian underground uranium mines from the 1940's to 1970's with an ongoing downward trend since then. The current situation in modern uranium mines is that radon levels are low and well controlled in most circumstances. Data presented from the situation in South Africa supported overall trend of improving exposures and showed that all workers are now meeting the dose limits, notwithstanding the ongoing efforts required to achieve these results. Finally, it is noted that it will be of importance in the future to apply radiation protection principles to non-uranium mines and workplaces.

An update of the new developments from the ICRP regarding radon exposure including ICRP publication 115 was reviewed and showed how the analysis of the epidemiological data had led to an approximate doubling in the nominal risk coefficient. The dosimetric approach to radon risk was reviewed, including a number of the key parameters. The ICRP's preliminary dose coefficients as calculated by the dosimetric approach were presented for the nominal home, indoor workplace, and mine environments. The calculated risks from the epidemiological studies and dosimetric approach show reasonable agreement with each other. The integrated and graded approach for the management of radon exposure from ICRP publication 126 was also reviewed. Finally, it was noted that the ICRP would publish new reference dose coefficients for the inhalation and ingestion of radon and its progeny.

The presentation by the new developments from the ICRP set the stage for some of the practical challenges from a regulatory and industry perspective. The presentation from South Africa highlighted the considerable efforts that have been undertaken over the last two decades to control and reduce radon progeny exposures in many underground mines. With a potential doubling of the calculated doses from radon progeny due to the new dose conversion factors from the ICRP, past optimization efforts will need to be re-examined. Work in this area could include improved monitoring, better ventilation, more control of radon sources, use of more rigorous administrative controls, and use of personal protective equipment. The potential doubling of doses from radon will also likely raise some concerns and the challenge of communicating the new radon risk information to concerned stakeholders was raised.

The elevated risk to radon from smoking was noted. Discouraging a workforce from smoking could have substantial health benefits and substantially lower their risk from radon exposure. In the area of gaps, with regard to the dosimetric approach of the ICRP, there is a lack of practical measurement equipment and techniques, along with little current data on required parameters in modern work environments. More work is needed in all these areas before the ICRP dosimetric approach can be applied on a routine basis in work environments. It was also noted that while there is relatively good data for uranium mines, there is very limited data on radon levels and exposures in non-uranium mines. The potential doubling of calculated doses from radon progeny exposures due to the new information from ICRP adds to the importance of filling in this gap. Now in most of the Member States, there is also an existing gap of legislative revision based on the ICRP new recommendations on radiological protection against radon exposure. It is noted that the mines are first treated as existing exposure situations, and they are also regulated as planned exposure situation based on Member States' regulations.

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

Occupational radiation protection (ORP) in health care is complex. Among the topics discussed include monitoring of staff, shielding, issues in interventional radiology and occupational radiation protection culture, including ethical issues. There is a need to customize individual protection, which is often seen as uncomfortable, distractive and inhibits performance. Shielding lacks global standardization and is generally poor in mobile x-ray units. In interventional radiology, appropriate room design is crucial, and this requires liaison with engineers and staff. Suspended ceiling and tableside lead shields are essentials. Good cultural practices need to be encouraged extending beyond individuals to the stakeholders, including professionals, unions, patients and the wider community. In daily practices, radiation protection culture needs to be examined, reflected on and become pervasive. The new Basic Safety Standards would facilitate enhanced radiation protection culture. The three S's (Standards, Shields, and Skills) are the main important factors to improve occupational radiation protection in medicine. Standards are required for equipment; Shielding should be purpose designed and skills and knowledge are needed in practice.

Improving optimization in occupational radiation protection in medicine remains an important task in this area. The majority of European countries have adopted dose constraints as an optimization tool for occupational exposure in the non-nuclear energy sector into their national legislation. The ORAMED project, established in 2008, focused on improving knowledge on exposures in medicine and on optimization of the use of personal dosimeters. The highest doses are received by staff working in interventional radiology, interventional cardiology and nuclear medicine, although there have been reductions in doses over the last 40 years. However, occupational doses may increase with the increasing frequency and complexity of interventional procedures. It should be remembered that the main source of scattered radiation is from the patient's body and by reducing patient dose, scatter is reduced and in turn the dose to the operator also reduces. Optimization can be improved by placing greater emphasis on the education and training of staff and by ensuring an appropriate equipment design and better regulatory frameworks.

Education and training of health professionals in the area of occupational radiation protection is also an important component in improving the radiation protection of workers. This emphasized the important role of a medical physics expert in the training of other healthcare professionals with regard to radiation protection. The MEDRAPET (medical radiation education and training) project, which commenced in 2010, highlighted the lack of harmonization of radiation protection training and education. Several organizations including the European Commission, IAEA, ICRP and EFOMP are active in the field of education and training in occupational radiation protection.

The occupational exposure of interventionalists is among the highest occupational exposure of all medical use of ionizing radiation. Many medical specialists are now involved in fluoroscopically guided procedures, often with no training in radiation protection. Using appropriate techniques and protection devices, interventionalists may keep their annual effective doses in the range of 2-4 mSv. Cataracts and opacities of the eye have been observed in up to 50% of interventional radiologists and cardiologists in some studies. The problem of wearing personal dosimeters in different sites on the person was highlighted, particularly as the reliability of staff wearing two dosimeters correctly and consistently is often questionable. The importance of wearing personal protection devices and using both ceiling and table mounted shielding was emphasized. The conference observed high interest in the subject, which became evident from the 42 contributed papers, on a wide range of topics, from 34 countries. Several common themes emerged. There was evidence that occupational doses are generally decreasing, although some high doses do still occur. Education and training was included in many papers, with recognition that radiation protection should be part of refresher training. Eye doses are a concern for interventionalists and while it is accepted that protection devices do work, they do have to be used. An important role of regulatory bodies in occupational radiation protection was highlighted. The discussion included the perception that many individuals in healthcare are still unaware of many of the issues of occupational radiation protection, using other imaging modalities, e.g., ultrasound and magnetic resonance imaging, which are useful for diagnosis and can be reserved for therapeutic intervention. Furthermore, the ethics of treating patients that may knowingly result in high doses to both the patient and, as a consequence, the staff was discussed. The main conclusions from all presentations were that all actions to protect patients and reduce their dose will, in addition, protect the staff and that both patient and occupational radiation protection should always be considered together.

NUCLEAR FUEL CYCLE FACILITIES

Occupational radiation protection (ORP) is extremely important in the different life cycle phases of a nuclear fuel cycle facility from the conception, through operation to decommissioning. The trends in occupational radiation exposure in nuclear fuel cycle facilities, available in UNSCEAR and ISOE databases, show a steady decrease of the annual collective dose and average individual doses. After an important decrease of the exposures in uranium mining about two decades ago, we see that nuclear power plant operation remains the main contributor to occupational collective dose within the nuclear fuel cycle. In average, the collective dose in the nuclear power plants is still going down, however, the reduction is less pronounced compared to the reduction seen twenty years ago. Different contributing factors have led to a general reduction of the collective dose. The evolution of radiation protection standards and the collaboration within the framework of international organizations such as ILO, IAEA, IRPA and NEA provided a solid base to efficiently implement the system of radiation protection. Within the industry, the markets for energy drive motivate the utilities towards better and more efficient work planning and operations. The introduction of new techniques and design improvements are also identified as contributors to the reduction of exposures. In recent years, we have seen technological improvements beneficial to individual dose measurement, dose management, radiation field measurement at the workplace, dose prognoses and robotics, all playing their role in the reduction of the exposure of the workers.

Another important factor is the efficient system, developed in nuclear industry, to distribute and exchange results from feedback of experiences and peer reviews on industry-wide safety and radiation protection. It is important to maintain and further improve this knowledge base established by the IAEA, NEA and ISOE through different symposia involving experts from industry and regulatory bodies. A knowledge base that covers the practical implementation, but also the scientific background, is an efficient occupational radiation protection. Another conclusion is that the collective dose is still an important management tool that enables to evaluate the effectiveness of the ALARA approach in a nuclear fuel facility, year after year. Intercomparison with other similar NPPs is also possible, although care must be taken to account for possible differences in activities between facilities. It is understood that the collective dose is a good indicator to assess the evolution of the effectiveness of the ORP in a facility, however, further information is needed on the detailed operations to clearly understand the trends in collective dose. It was identified that the ISOE system can provide all kinds of comparisons including typical dose rates of plant components and collective dose per worker groups. In the future, it could be beneficial to provide more easily additional data on the distribution of workers' individual exposures per dose intervals. The ALARA programme is a key to stimulate and involve operating organizations to implement ORP improvements in work planning, operations or design. A conclusion can also be related to the importance of considering ORP already in the design of a facility. The Expert Group on Occupational Exposure (EGOE) established by NEA and ISOE focused their attention on the integration of operational radiation protection in the design and conception phase of NPPs. This resulted in a practical guidance published as the report “ORP principles and criteria for designing new NPPs”. The guidance includes experience from previous designs, checklists and points of attention that can help in the design of new NPP’s in order to take into account ORP and ALARA in the design phase and avoid doses or supplementary dose reduction cost in operation. It is clear that the involvement and authority of ORP experts within operating organizations during the design phase or later in the decommissioning phase of nuclear power plants is paramount to implement an efficient ORP programme. This should be adequately recognized and requested within the framework of national regulation.

The national regulatory bodies in the countries embarking on nuclear power plants face many challenges in preparing the framework for occupational radiation protection. Establishing the ORP framework involves issuing regulations, guides and the implementation of adequate radiation protection programmes by the licensees. It also involves establishing and maintaining an adequate level of expertise in all domains of the nuclear field (nuclear safety, radiation protection, emergency preparedness). Again, the framework of international organizations such as ILO, IAEA, IRPA and NEA can provide, together with the embarking countries, a solid base to efficiently implement the system of radiation protection. Occupational radiation protection, good ALARA practices and an integrated risk approach are also important in the long-term operation and decommissioning of a facility. Good ALARA practice established already during the operation and previous design of the plant are important for the overall planning of the decommissioning process and for its work control. Early integration of ORP experts in planning is always necessary and there is a clear need to compare planned and real doses in order to enrich the use of experience feedback in the planning.

The ORP experiences at a reprocessing plant (i.e. Sellafield) illustrated that this site copes with a wide range of different processes including construction, operation and decommissioning all side by side at the facility. A flexible approach in ORP and ALARA is essential as the facility spans already sixty years of operation and contains installation of different ages based on design standards that evolved through the years. Experiences given through practical examples show that the evaluation and the decision in the ALARA process are influenced by the individual’s perception of risk, depending on experience/knowledge, level of control and perceived benefits from the operation performed. Sometimes it is beneficial to accept operations with a higher risk in the short term in order to reduce the risk in the long term. Waiting to find a perfect solution to perform an operation or to deal with an exposure situation can increase the risk in the long term. Over-conservatism in the dose prognoses of operations can also lead to the elimination of good and practical ways to perform the operation. Confronted with different risks, the organization should encourage a flexible and practical approach using a range of different techniques as needed to deliver an integrated risk reduction.

EDUCATION AND TRAINING

The significant contribution of the IAEA Regional Projects in developing a National Strategy in education and training in radiation protection was acknowledged. The development of national programmes on education and training (needs of analyses, design, development and implementation, evaluation of the programme) and building up Regional Training Centres (same language, same problems) should be further encouraged. The acknowledgment and accreditation of training in radiation protection is a challenge to be achieved in many countries. The IAEA should continue to provide guidance. The acknowledgment and accreditation of training in radiation protection is a challenge to be achieved in many countries and the IAEA should continue to provide guidance. Better regulation of education and training requirements in radiation protection as well as accreditation of courses/training, events/training centres on a national level is necessary in many countries to have a sustainable high-quality programme (graded approach). Where appropriate, upgrade high-level courses to master courses. Education and training, as well as continuous professional development in radiation protection, is important for the overall safety culture development. National and international professional RP associations can contribute to education and training improvement by supporting/organizing RP training events. The valuable role of networks in keeping up-to-date radiation protection knowledge and experience was emphasized and should be further supported by IAEA. Creation of RP networks on a local/national/regional basis: “learning from experience and sharing lessons learned” by professionals is a very valuable development and should be encouraged. Further work is still necessary to ensure appropriate planning to meet the need of trained professionals in radiation protection.

SAFETY CULTURE

Safety culture is certainly not a concept one can implement in an organization and then forget about it – it's something that needs to be lived and, as the name implies, to be cultivated so it becomes part of people's daily routine. IRPA presented the document ‘IRPA Guiding Principles for Establishing a Radiation Protection Culture’. The purpose of this document was to capture the opinion and standpoint of radiation protection (RP) professionals on the essential components of a RP culture and to help equip radiation protection professionals to promote a successful RP culture in their organization and workplace.

The conference noted the work of the Institute of Nuclear Power Operations (INPO) on Safety Culture and the achievements of the International System on Occupational Exposure (ISOE) to promote international exchanges on optimization of radiological protection. The presentation of the FORO (Forum for the Ibero-American Radiological and Nuclear Regulatory Authorities) document 'Safety Culture in organizations, facilities and activities with sources of ionizing radiation' describes indicators of safety culture and proposes ways to promote and develop a strong safety culture. Various topics such as the analysis of the impact of safety culture in the occurrence of radiological accidents and best practices to foster and develop safety culture are addressed in the appendices and annexes of the document. It is concluded that safety culture is an ongoing process and a learned way of life. Radiation Protection Culture is contained in the more general concept of safety culture and should be seen as the implementation of RP principles inside the framework of safety culture. Safety culture is not established at the same level in the different sectors i.e., nuclear and medical. The IRPA Guiding Principles as well as the FORO project publication are very helpful tools for any country or organization establishing or improving safety culture.

MAIN FINDINGS OF THE SYMPOSIUM

The second International Conference on Occupational Radiation Protection hosted by the International Atomic Energy Agency (IAEA) and cosponsored by the International Labour Organization (ILO) in Vienna, Austria, from 1 to 5 December 2014, is devoted to the enhancement of radiation protection of workers worldwide. The conference assembled over 500 delegates from 96 Member States. Subject matter experts in radiation protection and associated specialties from around the world reviewed the status of occupational radiation protection with the objective of enhancing protection of workers.

The IAEA has statutory responsibility to establish safety standards for protection against the risk to radiation exposure, including such standards for occupational protection, and also to provide for the application of those standards. It has been establishing such standards, including the revised Radiation Protection and the Safety of Radiation Sources: International Basic Safety Standards (BSS) General Safety Requirement (GSR) Part 3, for more than 50 years. The ILO has overall responsibility for occupational safety and health, which it discharges in the radiation protection area mainly through ILO Convention 115. This Convention has been ratified by, and has thus become binding on, over 50 countries. The ILO is also a cosponsor of the BSS and other international radiation safety protection standards. The IAEA and ILO, in cooperation with Member States and the sponsoring organizations, professional societies, employers, and employees work together to ensure protection of workers from ionizing radiation.

The overall message in the opening of and throughout the conference was that countries and multilateral organizations are working together to enhance protection of workers. Occupational radiation protection over the past several decades is a success story for the international radiation protection community by protecting workers and reducing occupational exposures. This is especially true for the protection of workers at nuclear installations around the world. As a result of local economic, social and political conditions, gaps and challenges remain where the picture is not as clear or compelling. Focused effort by multilateral organizations, Member States, licensees, operators, employers, and employees is required to close the gaps and overcome the challenges to enhance protection of workers. In addition, as the workforce ages and new workers begin working, transfer of knowledge of the highly successful radiation protection principles, framework, and tools is required to ensure that the high level of protection will continue long into the future.

The standards for radiation protection developed at the international level are generally satisfactory as a framework for the control of occupational exposures in developed and in developing countries. Changes to the standards should only be made where necessary to reflect enhanced scientific understanding of the effects of ionizing radiation exposure or to fill gaps, improve clarity, facilitate application, or ensure the necessary level of protection. Unjustified changes can have unexpected and negative side effects and can undermine confidence in the radiation protection system, if not properly justified and clearly communicated. Continued attention to the development of the ethical basis for radiation protection will assist consistent application and improve understanding and communication.

With respect to consideration of the recommendations of the International Commission on Radiological Protection (ICRP), as far as occupational exposures are concerned, further major modifications of the international standards do not appear necessary. The international safety framework for protecting workers is well established and effective, including application of the three fundamental principles of justification, optimization, and dose limitation. However, implementation of some of these recommendations in some areas, such as medicine and work involving exposure to elevated levels of naturally occurring radiation is complex.

Exposure to natural radiation is an inescapable feature of life. All workers are exposed to natural radiation whether they are working or not. When action is possible and justified, workers exposed to natural radiation should be given the same approach to protection, including optimization, as those exposed to radiation from artificial sources. Focus should be placed on workers receiving higher levels of exposure. Clearer international standards and guidance is needed to assist employers and regulatory authorities in applying a graded approach of protection, including applications to radon and progeny.

In industrial and research facilities, occupational doses are generally quite acceptable. There are, however, specific industrial and research facilities that involve higher routine exposures and occasional accidents with significant exposure consequences. A primary example is industrial radiography, which is performed in difficult environments by individual workers and where safety relies largely on adherence to procedures and human performance. High occupational exposures associated with accidents may be caused by a failure to follow procedures and appropriate monitoring, including the use of alarming dosimeters and other radiation monitoring. Improved worker training, improved safety culture, practical ways to optimize exposure in the wide variety of working environment and sharing of operating experience could enhance worker protection for these facilities and applications. For example, an effective model for such sharing is the Information System on Occupational Exposure that is used to share dose reduction information and operational experience to improve the optimization of worker radiological protection at nuclear power plants.

Exposures of workers in medical applications, including the use of conventional radiology for diagnosis and therapy, are generally well controlled and the procedure is in accordance with the international safety standards. There are, however, new and emerging medical practices, especially interventional radiology and interventional cardiology, in which higher occupational exposures are occurring. These exposures to both workers and patients are growing as the procedures are being used with increasing frequency. There is a broad recognition that actions taken to protect patients from unnecessary radiation exposure also contribute to protecting workers. The contributions of medical physicists have also succeeded in reducing worker and patient exposures. Sufficient attention should be paid to the optimization and control of these exposures, through design (e.g., shielding) and conduct of the procedures, monitoring of exposures, improving safety culture and awareness of best practices and optimization, and improved training and education of the medical professionals, including physicians, nurses, and other workers who contribute to successful health outcomes and occupational radiation protection.

Radiation protection should be an integral part of the general health and safety protection of workers and of safety regulation and management systems in the workplaces. Workers may face a wide range of occupational hazards and unduly protecting workers against one or a few hazards may be detrimental to occupational safety and health, if such protection undermines protection against other comparable or greater workplace hazards. Radiation hazards are just one type of hazard to which workers are exposed, and these hazards may be more or less significant than other occupational hazards. In some settings, radiation protection may be of secondary or tertiary importance. Therefore, application of radiation protection measures, including application of optimization, must be examined within the context of the totality of workplace hazards, thereby using resources to achieve the greatest gain in worker protection. A more holistic approach is needed that recognizes and appropriately protects against this large range of hazards. In addition, although social and economic factors are taken into consideration in applying the optimization principle, there should be no fundamental difference in standards of protection between developed and developing countries. For the sake of worker protection and credibility, international standards must be applied uniformly and effectively. Operating experience in protecting workers must also be shared and used to make appropriate revisions to the standards and facilitate their effective application.

VIENNA CALL FOR ACTION

Based on the first conference in Geneva in 2002, 14 action items were identified and each of them has been successfully accomplished during the intervening years. Similarly, the 2014 Vienna conference identified a number of desirable actions to enhance protection of workers, including:

Enhancing training and education in occupational radiation protection to equip workers with the necessary knowledge, skills, and competencies to accomplish worker protection, including periodic refresher training in radiation protection and practical measures to reduce exposures.

Improving safety culture among workers who are exposed to ionizing radiation, including promotion of safety culture by regulatory authorities through outreach and education.

Developing young professionals in radiation protection particularly for developing nations, through communication, networking, training, research, hands on experience, and participation in technical meetings and conferences.

Implementing the existing international safety standards to enhance occupational protection of workers, including assisting Member States in facilitating implementation and encouraging a holistic approach for worker protection.

Developing and implementing new international safety guides for occupational radiation protection in different exposure situations, including advanced accelerator facilities and interventional radiology.

Promoting exchange of operating experience, particularly for industrial radiography and medical radiology and including appropriate consideration of human factors, not just among Member States and regulatory authorities, but also among operators, radiation protection officers, and vendors.

Convening an appropriate international forum to exchange additional information and analysis of worker protection in different exposure situations, including during nuclear emergencies to identify lessons and implement plans for the protection of workers and helpers, enhance worker preparedness, guide the rapid transition from planned exposure to emergency response, and improve radiation protection in emergencies.

Applying the graded approach of the BSS in protecting workers against exposures to elevated levels of naturally occurring radiation or radioactive materials, including flight crews, miners, and other workers.

Enhancing assistance to Member States with less developed programs for occupational radiation protection to support practical implementation of international safety standards.

OPENING SESSION

Chairpersons

M. Pinak

International Atomic Energy Agency

P.S. Hahn

International Atomic Energy Agency

Statements are as provided, verbatim.

OPENING ADDRESS

Y. Amano

Director General,

International Atomic Energy Agency,

Vienna, Austria

Good morning everyone and welcome to Vienna. It's a great pleasure for me speak to you today on this important subject.

The first Occupational Radiation Protection Conference was held in 2012 in Geneva, 12 years ago. It ended with Action Plan on Occupational Radiation Protection. As part of this Plan, the Occupational radiation protection has been well recognized and established part of the radiation protection system. Scientific information available from UNSCEAR as well as occupational exposure data available in the International System of Occupational Exposure reveals positive trends in many key performance indicators like for example dose reduction information, operational experience and improvement of the optimisation.

Exposures in medicine and industry, and exposures to natural sources, especially in mining need continuing attention, and need to be addressed globally. Despite positive trends seen in decreasing occupational exposure, there are still occurrences of contamination or exposure to workers, non-equity of distribution of doses among workers, etc. These occurrences suggest that implementation of the optimization principle of radiation protection may still need more attention by managers.

The recently revised and published this year International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) introduce a system of radiation protection of which the provisions for occupational exposure are the substantial component. The revised BSS are co-sponsored by 8 international organisations, and in the area of the occupational exposure the revision was strongly supported by the ILO, co-sponsor of this conference. The IAEA has been holding national and regional workshops to introduce the revised BSS and to offer assistance on implementation of the revised requirements.

This conference aims to provide an update to and acknowledge the good progress made since the last conference. It also aims to identify areas in which more work still needs to be done. IAEA remains committed to these efforts, your support and commitment is vital. I wish a very productive week.

OPENING ADDRESS

D. Flory

Deputy Director General,

Department of Nuclear Safety and Security,

International Atomic Energy Agency

Vienna, Austria

Good morning, ladies and gentlemen.

It is my great pleasure to welcome you here and I would like to express my sincere wish that this Conference be a milestone in the field of occupational radiation protection.

The main aim of the conference is to formulate conclusions and recommendations for occupational radiation protection for the coming years and decade, through reviewing advances, challenges and opportunities and identifying areas for future improvement.

The Conference is organized by the IAEA, co-sponsored by the International Labour Organization (ILO), in cooperation with 15 other international organizations and bodies, and I am pleased to have the opportunity to express the sincere gratitude of the Agency to all our partners for their effort to make this conference a success.

The first conference held in 2002 ended up with the International Action Plan on occupational radiation protection. This action plan has been driving the improvement of occupational radiation protection worldwide effectively and efficiently. Since then, the IAEA has issued a number of safety standards and technical guidance and carried out technical cooperation projects on occupational radiation protection with the cooperation of other regional and international organizations and the Member States. There has been a clear diminishing trend in the dose that workers receive in the course of their work, while the number of occupationally exposed workers has continuously increased. The implementation of the standards and guides published by the IAEA has indeed played a role in this trend of decreasing doses.

Developments and challenges

I am happy to briefly share with you selected developments during recent years:

Firstly, as already mentioned in the Director General's welcome address, the revised International Basic Safety Standards have been published in July this year. It is a product of a joint effort, cosponsored by eight international organizations. The associated Safety Guide on occupational radiation protection is currently in the preparation and we foresee its publication in 2015.

As another example, the information systems and networks are a very important part of the occupational radiation protection system. They enable and enhance the needed information exchange among various parts of the system like for example utilities, regulators, national and international bodies. These systems and networks have also been gradually developed and applied in recent years. The Information System on Occupational Exposure, ISOE, is one of these very important networks. The number of participants of the ISOE has continuously increased with the commissioning of new nuclear power plants. The occupational radiation protection of these nuclear power plants has benefited significantly from the ISOE. Another similar system currently being developed is the Information System on Occupational Exposure in Medicine, Industry and Research – ISEMIR that we have initiated. It has two parts, one dealing with occupational doses in interventional cardiology, another with industrial radiography. The ISEMIR-Interventional Cardiology was uploaded on the website of IAEA in 2013. The ISEMIR-Industrial Radiography is going to be published in early 2015.

I have just mentioned a few examples of how good practices and experiences in radiation protection in specific areas can be shared and disseminated through such networks.

Despite this progress, there still remain a number of specific challenges in most of the areas in occupational radiation protection. For example:

Medical applications of ionizing radiation represent the largest manmade sources of ionizing radiation. The number of occupationally exposed workers in medical facilities has been increasing rapidly over the years, and individual occupational exposure varies widely among those involved in medical care. There are certain medical procedures that might give substantial doses to medical staff.

The extremely extensive distribution of industries involving Naturally Occurring Radioactive Materials, calls for radiation protection in these industries to be addressed and potentially strengthened in terms of identifying the activities giving rise to radiation exposure, and applying a graded approach to control related exposures.

The construction of nuclear power plants in embarking countries, and the introduction of novel designs of nuclear reactors have also given rise to some new issues. For example, there is a need to address comprehensively radiation protection aspects already at the design phase of new NPPs. On the other hand, as many nuclear reactors come to the end of their operating life, decommissioning activities are expected to increase significantly, and this may result in additional challenges for occupational radiation protection. The IAEA is now preparing the material that will address radiation protection in both areas – new NPPs as well as those in a decommissioning phase.

The Fukushima Daiichi nuclear accident has highlighted various challenges in terms of approaches, measures and actions for radiation protection of workers in emergency situations. For example, monitoring programmes, in particular for those workers receiving high doses and those subject to internal exposures, are necessary to reduce uncertainties in exposure assessment. Health surveillance for emergency workers exposed to high doses also needs further consideration.

Exposure of aircrew to cosmic radiation, radon at the workplace other than mines and protection of pregnant women against radiation continue to be of concern to the affected workers and to some of the national regulatory bodies. The IAEA highlighted in the recently revised BSS the need to address radiation protection of the aircrew.

With increasing mobility of the workforce worldwide, radiation protection of itinerant workers requires further attention. It needs to address issues associated with the qualification, dose monitoring and recording. The IAEA has recently completed the material addressing specifically this category of workers.

Ladies and gentlemen,

Coming to the end of my talk I would like to underline that the goal to ensure adequate and satisfactory level radiation protection around the world is a mission for all of us - national regulators, nuclear plant operators, research institutions, governments as well as international organizations. We can accomplish this only through working together, learning from each other, and assisting each other.

Over the next five days, you will have the opportunity to share your professional views and experiences on occupational radiation protection. I wish you a very productive meeting and I am convinced that you will take advantage of the time you spend together this week to enhance our common knowledge and understanding of occupational radiation protection issues.

Thank you for your attention.

OPENING ADDRESS

N. Leppink

International Labour Office,

Geneva, Switzerland

Distinguished guests

Good morning ladies and gentlemen, Mr. Flory, Deputy Director General of the IAEA and Mr. Weber, Conference President.

On behalf of the Director General of the International Labour Organization, Mr. Guy Ryder, I warmly welcome all of you. The ILO is extremely pleased to co-sponsor this second international Conference on Occupational Radiation Protection.

This conference is convened as a result of the close cooperation between the conference host – the IAEA and its co-sponsor the International Labour Organization, and also in cooperation with the European Commission, the International Commission on Radiation Units and Measurements, the International Commission on Radiological Protection, the International Committee on Non-Destructive Testing, the International Mining and Minerals Association, the International Organization of Employers, the International Radiation Protection Association, the International Organization for Standardization, the International Society of Radiology, the International Society of Radiographers and Radiological Technologists, the International Trade Union Confederation, the OECD – Nuclear Energy Agency, the Pan American Health Organization, the United Nations Scientific Committee on the Effects of Atomic Radiation and the World Health Organization. I thank the IAEA for its commitment to involve all the stakeholders in its work on the protection of workers against exposure to ionizing radiation.

Being the joint convener of the first conference on this topic, the International Conference on Occupational Radiation Protection: Protecting Workers Against Exposure to Ionizing Radiation, held at the ILO Headquarters in Geneva, Switzerland in August 2002, the ILO is very happy that this second conference will review the progress that has been made over the last 12 years and to define needed future work.

This conference, with its theme “Enhancing the Protection of Workers – Gaps, Challenges and Developments” provides the opportunity since the first conference on this topic, to identify areas for future improvement and to elaborate on a vision and strategies for the better protection of workers against their occupational exposure to ionizing radiation.

Challenges from the Fukushima Daiichi nuclear accident have highlighted the need for better monitoring programmes in particular in emergency situations, the better assessment of occupational exposure due to intake of radionuclides and better health surveillance for radiation workers. In addition, issues such as exposure of aircrew to cosmic radiation, radon at workplaces other than mines, and the protection of pregnant women against radiation are emerging as concerns not only for affected workers but also of national regulatory bodies. Further, radiation protection poses challenges for national regulatory authorities in their efforts to ensure compliance with dose limitations in view of the increased movement of skilled workers from one place to another and the widespread practice of sub-contracting now in the nuclear industry. The large number of international experts and professionals participating in this conference provides an excellent opportunity for the world community on radiation safety and protection to examine these challenges and share experiences over the coming days.

Work related to deaths and injuries including those caused by exposure to radiation take a particularly heavy toll in developing countries, where national systems for occupational safety and health, including labour inspection systems, are not well established and are ill matched to meet an increasing number of industrial activities and in particular hazardous work and where a workplace culture of compliance and risk control are not in place. According to the ILO estimates, occupational accidents and work-related disease cause over 2.3 million fatalities each year, out of which 350,000 are caused by occupation accidents and close to 2 million by work-related disease. This means every day 6,300 people die because they went to work.

The ILO was founded to promote social justice as a contribution to universal lasting peace. Its mandate is to ensure everyone the right to earn a living in freedom, equity, security and dignity, in short, the right to decent work. The ILO creates international labour standards including standards on safety and health at work and has a unique system to supervise their application. The ILO Convention concerning the protection of workers against ionizing radiation, Conventions 115 and its accompanying Recommendation 114 have been the only international legal instruments on radiation protection of workers. The convention applies to all activities involving exposure of workers to ionizing radiation in the course of their work. Requirements concerning the safety and security of radioactive sources are included in these international legal instruments.

At the global level, we cherish our good cooperation with the IAEA and other international organizations on setting international guidelines and standards on radiation safety and protection. We believe that such cooperation not only facilitates the implementation of the ILO Convention on radiation protection by our constituents but increase, at the national level, the synergy and impact of the relevant international polices on radiation safety and protection formulated by other sister organizations. Our common goal is that our activities would not only be complementary but mutually supportive.

The ILO also uses in a coordinated manner the various means of action available to it to provide support and services to governments, employers' and workers' organizations in the development and implementation of programmes that will contribute to the safety and health of workers and workplaces. Accidents occur not only because of lack of knowledge of safety rules but in many cases because of the lack of will.

The ILO expects enterprises and workplace to follow effective occupational safety and health management systems to avoid injuries and disease at work to achieve this, there is a need for:

Clearly defined national policies, that result in national standards and laws that are enforced;

National structures and mechanisms, in particular a clear understanding of who is in charge of what;

The designation of responsibilities and accountability and allocation of resources;

National action plans and programmes;

Follow-up, monitoring, review, feedback to enhance the process using carefully selected indicators; and

Continuous improvement in measurable steps at the national level.

Having a safe and health workplace is a human right. Respecting this human right is an obligation — as well as a condition — for sustainable economic development. I want to thank all of the participants today for continuing your important and daily work on radiation protection and safety. The ILO will continue to support its constituents, namely employers, workers and governments in their efforts to achieve a safe and healthy working and living environment for all workers and all people.

In the coming days, there will be many presentations that will provide useful insights on how we can better protect workers against exposure to ionizing radiation. Practical measures should be developed and carefully implemented to solve workplace occupational radiation protection problems in addition to imparting technical knowledge of academic value. It is my hope that this conference will be the continuation of concrete actions to improve and strengthen the protection of workers against hazards in particular ionizing radiation in the workplaces.

I wish you every success for fruitful deliberations that will bring valuable benefits for the future of the safety and health of workers throughout the world.

Thank you!

OPENING ADDRESS

M.F. Weber

President of the Conference,

United States of America

Respected dignitaries on the dais, distinguished delegates, ladies and gentlemen

It is Excellences, distinguished colleagues, ladies and gentlemen, good morning and let me add my welcome to this International Conference on Occupational Radiation Protection. I am honored to chair this important conference on protecting a most vital global asset, our workers. Our conference builds on the success of the 1st international conference in Geneva, Switzerland, in August 2002.

Special thanks to the International Atomic Energy Agency and the International Labour Organization for organizing, sponsoring, and hosting this conference. We also appreciate the support of and welcome the participation of our cooperating organizations, including;

European Commission (EC);
International Commission on Radiological Protection (ICRP);
International Committee for Non-Destructive Testing (ICNDT);
International Commission on Radiation Units and Measurements (ICRU);
International Mining & Minerals Association (IMMA);
International Organization of Employers (IOE);
International Radiation Protection Association (IRPA);
International Organization for Standardization (ISO);
International Society of Radiology (ISR);
International Society of Radiographers and Radiological Technologists (ISRRT);
International Trade Union Confederation (ITUC);
OECD-Nuclear Energy Agency (OECD/NEA);
Pan American Health Organization (PAHO); United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR);
World Health Organization (WHO).

This 2nd conference on occupational radiation protection is devoted to the protection of workers around the world against exposures to ionizing radiation. There are now more than 23 million workers, who are occupationally exposed to ionizing radiation. This number continues to grow. The participation in this conference of over 500 official delegates from about 100 Member States is a strong indication of the importance of and the seriousness of our collective efforts to protect workers.

Since the first conference in 2002, our Japanese colleagues suffered from the triple tragedy of the Great East Japan Earthquake and tsunami on March 11, 2011, and the nuclear disaster at Fukushima Dai-ichi that ensued. Despite this significant tragedy, our system for occupational radiation protection provided a fundamentally sound framework for protecting the workers who responded heroically during and after the disaster. The event also revealed some radiation protection issues that need to be addressed in emergency exposure situations. Similarly, the framework has successfully been used to protect workers around the globe from less demanding situations. Consistent with the conclusions of the 2002 Geneva Conference, occupational radiation protection remains a success story for the workers and the international radiation protection community.

As we commence this conference, I call our collective attention to answering three essential questions: Who, What, and How?

Who? Who accomplishes occupational radiation protection today and in the future? Workers, operators, vendors, and regulators. Clearly our success in occupational radiation protection is achieved through the diligent efforts of each of these groups. Yet, are we positioned for success as the global workforce evolves? Are we effectively equipping workers with the systems, knowledge, tools, and safety culture to achieve a high level of success in occupational radiation protection?

What? Occupational radiation protection occurs today consistent with the revised Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Application of the Basic Safety Standards works well in accomplishing radiation protection in mature industries with effective controls and optimization. But does the BSS work as effectively in achieving protection of workers in other occupational settings, such as the 12 million underground miners who are exposed to natural sources of radiation that may be enhanced in their setting? And what about situations where the state of the technology is rapidly evolving, such as interventional radiology and other medical applications, where health care professionals make real-time trade off decisions to balance the risks to the patient and to themselves while improving the health care outcomes for the patient?

How? How can we, the international community, best sustain and enhance occupational radiation protection, recognizing scientific advances and economic and social factors, including the benefit and costs of revisions to the standards? Society has improved occupational radiation protection by placing greater emphasis on optimization as a driving principle. But how well are we applying this principle in settings where the worker's income depends on their productivity and higher productivity incurs greater exposures? How well are we taking into account the economic and cultural environment and respecting workers' rights to make informed decisions in applying optimization?

Who? What? How?

In closing my opening, I remind our distinguished delegates of our conference objectives to:

- Exchange information and experience in the field of occupational radiation protection;
- Review advances, challenges, and opportunities since the first conference on this topic;
- Identify areas for future improvement; and
- Formulate conclusions and recommendations.

We would like to thank the authors for contributing numerous and interesting papers, as well as posters that are displayed in the rear of the conference room and are intended to foster the objectives of our conference. In addition, I'd like to thank our exhibitors for their support and contributions to achieve a successful and productive conference. I would also like to thank the Conference Secretariat, the Scientific Programme Committee, and the Organizing Committee for their numerous and tireless efforts to convene and achieve a successful conference.

Our conference builds on the firm foundation forged by our predecessors and prepares the world for future success in occupational radiation protection. Enjoy, engage, and enhance!

KEYNOTE ADDRESS

Past and Present Perspectives in Occupational Radiation Protection

K. Nakamura

Nuclear Regulation Authority, Japan

Abstract

Radiation protection at workplaces has been evolving for decades. The outcome of the first international conference on occupational radiation protection as an international action plan has been completed and a lot of progress has been achieved in the field of worker protection from exposure to ionizing radiation. The paper reviews the developments including the need for adequate standards for occupational radiation protection especially in the context of Fukushima Daiichi accident and outlines future perspectives.

The first International Conference reflecting on the entire area of occupational radiation protection was organized in Geneva in 2002. It has already been 12 years since the recommendations in occupational radiation protection, as an outcome of the Geneva Conference, have been expressed. The conclusions were summed up and merged into the International Action Plan for Occupational Radiation Protection (IAPORP), prepared by the International Atomic Energy Agency (IAEA) in co-operation with the International Labour Organization (ILO).

A lot of progress has been achieved since then in this field. The important elements of today's knowledge on occupational radiation protection are anchored in existing reporting, data keeping and knowledge sharing systems such as The Information System on Occupational Exposure - ISOE network. This network has been created in 1992 in order to provide a forum for radiation protection professionals. Various regional networks such as ALARA networks also function with a similar aim. These important systems and tools show a decreasing trend of occupational exposures. We are here today not only to review these past advances, but also to face together the remaining challenges and formulate possible solutions.

Even despite the efforts undertaken after the Geneva Conference, we all recognize that much work still remains to be done in various fields of the occupational radiation areas. The number of occupationally exposed workers in medicine has been continuously increasing due to a high number of procedures giving substantial doses to radiological medical practitioners and other technical staff, for example in interventional radiology. There is a tremendous need to address these issues among the ones exposed in medical care. There are also requirements for regulations in NORM industries, where workers face high levels of natural radionuclides. Since only less than half of the world's occupational workers are exposed to artificial radiation sources, we need to identify the activities that give rise to this kind of radiation exposure.

In these and other industries, radiation protection needs to be strengthened. In order to increase safety of workers and to control their exposure, the current regulations need to be in accordance with the IAEA Safety Standards, in particular with the recently published Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards - No. GSR Part 3 (BSS). While these standards establish a system of radiation protection of which the provisions are a substantial component, the 2007 Recommendations of the International Commission on

Radiological Protection (ICRP) stand on three fundamental stones of radiological protection, namely justification, optimisation, and the application of dose limits.

What the term occupational radiation protection currently represents in Japan is nearly the same as the concept understood by the ICRP and by the BSS. Based on this internationally recognized concept, the values of criteria and the way of enforcement have been stipulated in the legal frameworks such as the Act on Prevention of Radiation Hazards due to Radioisotopes; the Reactor Regulation Act; the Medical Care Act; the Act on Medical Radiology Technicians; the Act of Occupational Safety and Health; and Regulations for occupational radiation protection relating to the above-described Acts.

With the reference to the 2007 Recommendations of the ICRP, several points with international significance have been discussed in Japan. These include the necessary health surveillance and health services; the provision of information on the risk to embryo or foetus; female workers who have notified pregnancy or who are breast-feeding; and workers in existing exposure situation (e.g. exposure due to radon, exposure of aircrews due to cosmic radiation).

In terms of the operation of nuclear facilities and the management of radioactive materials in the time of normal situation in Japan, the issue of occupational radiation protection had been deliberated gradually but steadily. The JCO nuclear criticality accident in the chemical processing facility in Tokai-mura in 1999 was one indication bringing the attention on the occupational radiation health effects associated with occupational exposure. The accident of Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Station (NPS), which occurred on 11 March 2011, further opened the "Pandora's Box", and direct questions on the adequacies deliberations regarding issue of occupational radiation protection were acknowledged.

The keynote speech does not highlight what we failed after the accident at Fukushima Daiichi NPS. It touches upon the fact that containing the accident could not be realized without the workers' courageous actions based on their understandings on radiation exposure. Such brave efforts and learnings are going as we speak. This keynote speech, among others, also addresses the efforts to move forward and reveal the contents of the "Pandora's Box" that we opened.

After the accident at Fukushima Daiichi NPS, the Radiation Council in Japan discussed to promptly focus on the safety management of contaminated materials derived from the release of radioactive materials by the accident, and on the radiation protection from the contaminated materials.

The Radiation Council has concluded that among other issues, the dose limit, which has been specified by the Regulations for Installation/Operation of Nuclear Reactors, should be 250 mSv in terms of the effective dose in the area of emergency response activities during the period from the day when the nuclear emergency was declared by the Prime Minister to the day when its declaration was lifted. Another decision was made concerning the exposure limit for workers in the area of emergency response activities, which should be 250 mSv during the above-described period. Later, it was also announced that TEPCO should ensure the effective dose limit for workers on site of Fukushima Daiichi NPS is not more than 100 mSv for 5 years, and is not more than 50 mSv for one year. In addition, the effective dose limit for workers for decontamination (e.g. removal of contaminated soil) should not be more than 100 mSv for 5 years, and should not be more than 50 mSv for one year.

Another outcome of the accident at Fukushima Daiichi NPS is the change in the perception of occupational exposure. In the past, occupational exposure used to be perceived from the viewpoints that such exposure is justified by the sense of obligation towards work. However, after the accident, the lesson was learned that the adequate communication of health effects associated with occupational exposure is very important in order to alleviate their concerns.

Rather than developing a concept of occupational radiation protection for justifying occupational exposure, it is critically important to develop the concept through which radiation exposure should be understood correctly by workers and their families. The development of this concept must take into account the following questions:

What level of radiation exposure can be acceptable for workers who engage emergency response on site of nuclear facilities during emergencies?

What level of radiation exposure can be acceptable for workers who engage management of radioactive materials in mid and long terms after nuclear emergencies?

What level of radiation exposure can be acceptable for workers who have the increasing possibility of radiation exposure with the development of science and technology?

Answers to these and other questions may vary among countries. Yet, what is essential to all occupationally exposed workers worldwide is to provide adequate information about occupational exposure and associated health effects.

PLENARY PRESENTATION

Challenges on Occupational Radiation Protection in Nuclear Industry

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Abstract

To deal with the challenges on occupational radiation protection (RP) in nuclear industry, the analysis shows that the actions carried out during the last few years about RP management and technical issues will help, but, some new orientations will be necessary to master the collective and individual doses. A "post ALARA" principle is proposed.

INTRODUCTION

The aim of this paper is to present the actions taken in the field of radiation protection in the nuclear industry, to make an assessment and especially to identify the challenges ahead and to suggest ways of working within radiation protection in order to prepare the future of the nuclear industry.

My experience as a former President of the ISOE Network, but mostly my experience as a specialist radiation protection contractor in the field, then RP manager on site, and finally RP engineering allows me to establish an assessment of the developments in recent past years and provide an analysis of the actions to be taken so that the protection of workers remains at the highest possible level.

The main question is: will it be possible to continue the trend of dose reduction that has been successful since the late 1980s?

Figure.1 shows the evolution of the collective dose per reactor type, taken from the ISOE database (network created in 1992).

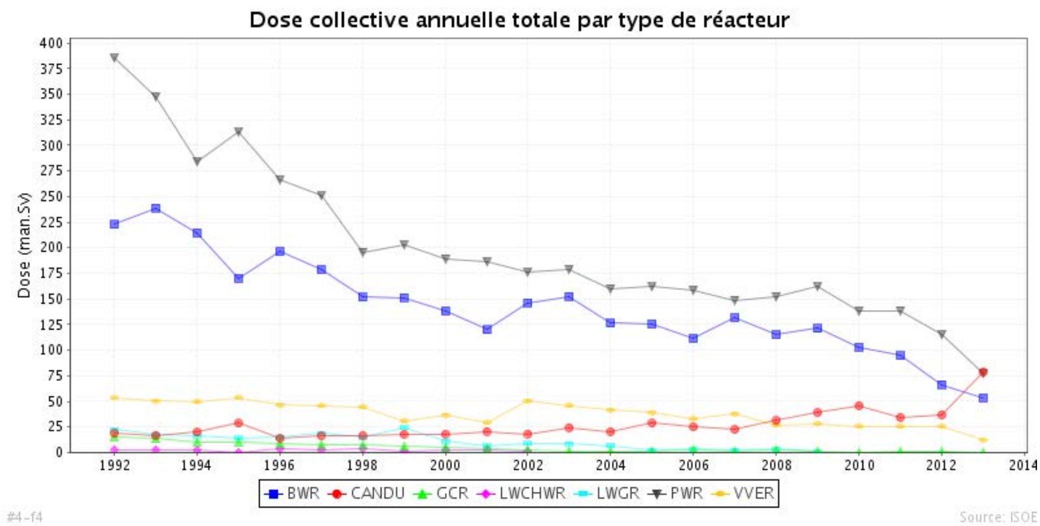


FIG. 1. Evolution of collective dose per reactor type (ISOE database)

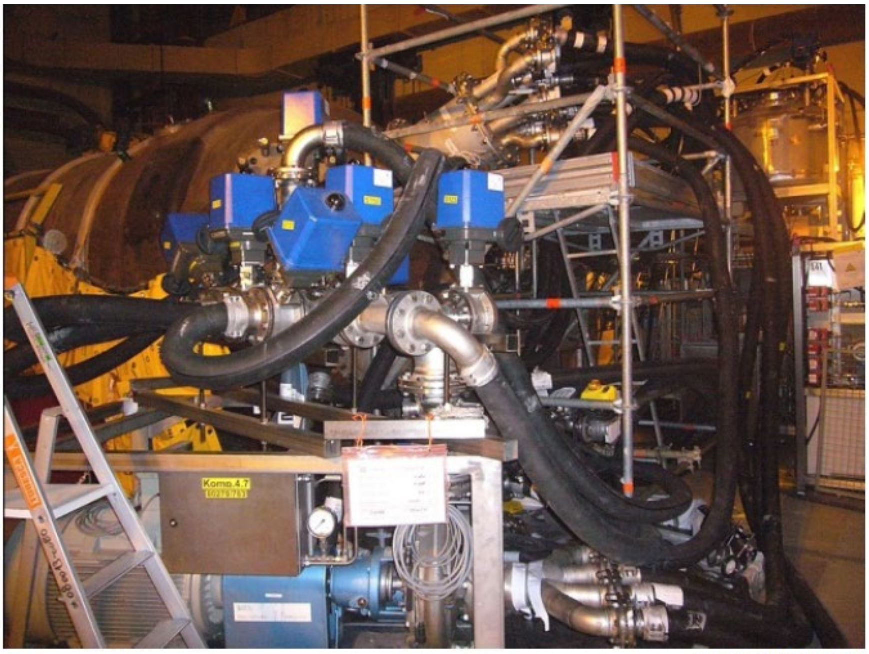
COLLECTIVE DOSE DECREASING FACTORS

The actions launched in the nuclear industry in recent years, as part of widespread deployment of ALARA and which must continue to have effect, are the following:

First and foremost, the evolution of RP management: RP is now integrated into the management of the NPPs, the responsibilities are clearly defined, and the decisions taken by the management are subject to justifications and are recorded. These decisions are made based on the advice of RP experts working with a direct link to production and maintenance activities. ALARA is seen by managers as an opportunity to advance in the field of radiation protection, and also in other areas such as production, and also, for example, social relations within companies and business relationships with suppliers and providers.

Source-Term management actions, whether preventive or curative, are a major factor for dose reduction management. In the area of prevention, the ISOE publication could be mentioned, from a working group in 2014: Radiation Protection Aspects of Primary Water Chemistry and Source-Term Management Report. This report gives a state-of-the-art of reactor primary circuit chemistry and must above all serve as a basis to create a link with a strong technical base between the operations, chemistry, logistics and radioprotection departments. For the corrective actions, the pursuit of remedial actions in the NPPs which allow, either of the scale of a complete reactor or by local actions on contaminated circuits, to reduce the dose. The procedures and the methods of chemical and mechanical decontamination are now available and can be implemented on the most contaminated units and/or in anticipation of major modification, maintenance and decommissioning work.

Figure 2 shows an example of decontamination carried out on the Chooz A (France) site in the course of dismantling [1].



Picture: AREVA & EdF

FIG. 2. Decontamination during dismantling at Chooz A site

The technical means of workplace monitoring have been developed. They allow remote workplace monitoring, limiting the dose to radiation protection personnel, and also it guarantees rapid assistance to workers in case of abnormal situations. Training of workers in technical actions widely uses recordings made during the performance of work.

Figure 3 is an example of Computer Risk Prevention Monitoring developed and implemented in EDF (France).

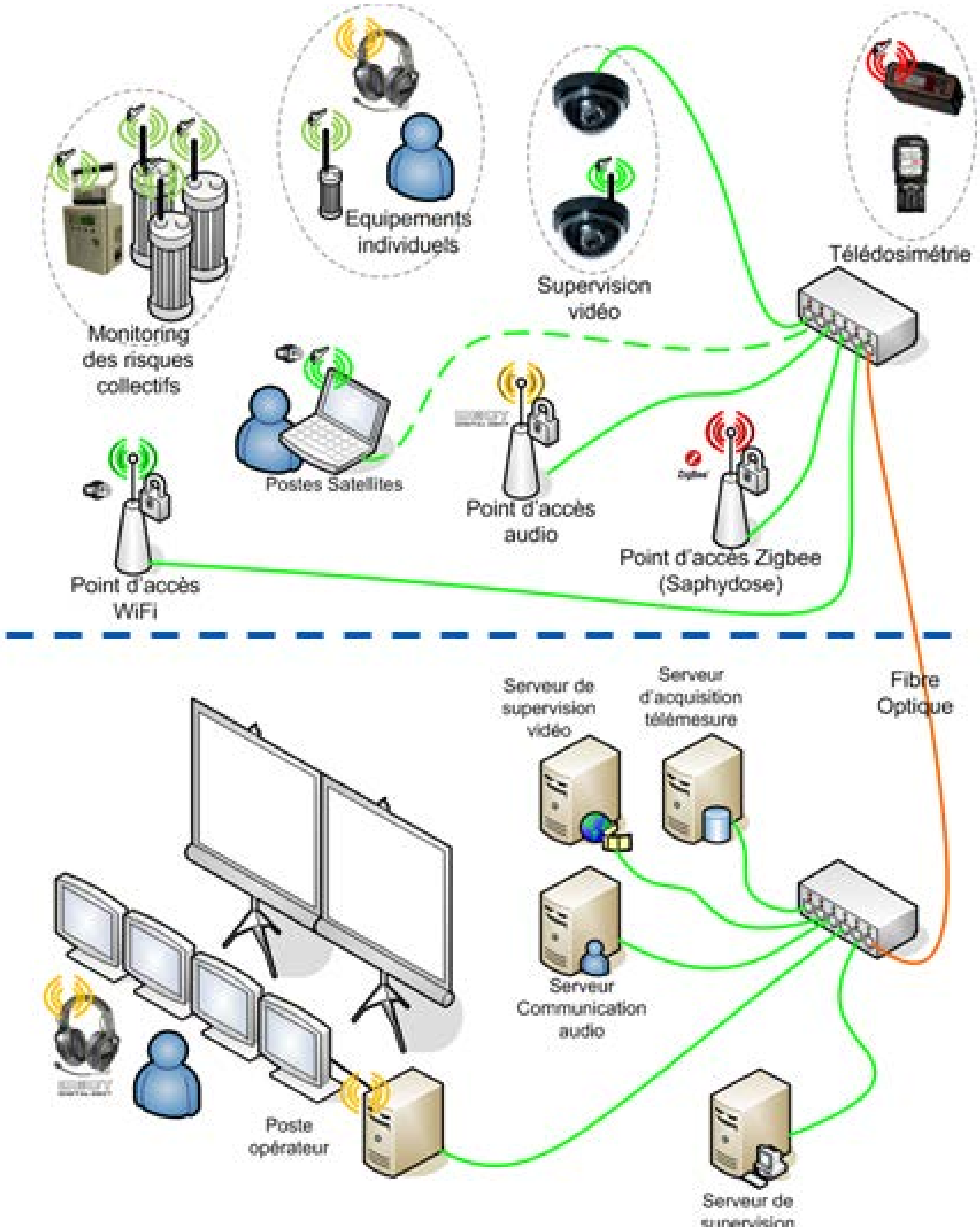


FIG. 3. Computer risk prevention monitoring

The means for measuring the radioactivity also progressed significantly; they are more reliable, more responsive and accurate. Technical innovations such as Gamma-Camera to permit comprehensive tracking and remote from sources of radiation are likely (e.g.: gamma camera). Fig.4 is an example of the image obtained [2].

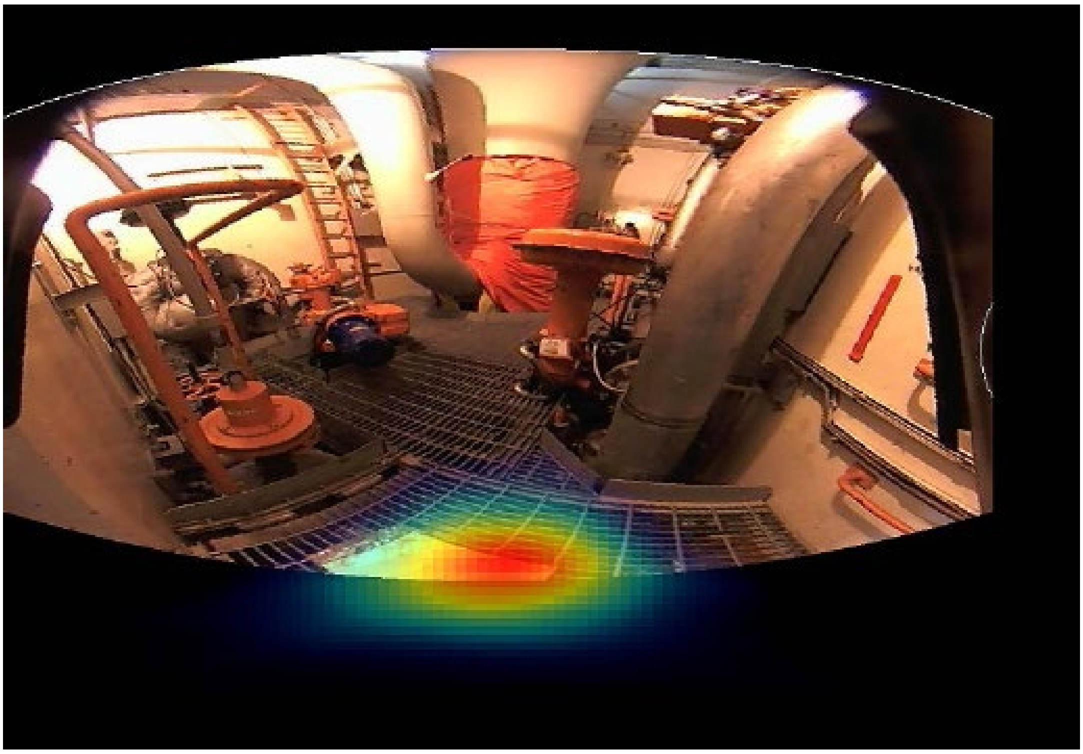


FIG. 4. Example of a gamma camera image

The integration of RP in the design of new reactors is a condition for the success of new nuclear power plants. These actions in limiting dose should allow maintenance of a level of exposure as low as possible, and should also allow the implementation of very large industrial projects. The implementation of the ALARA approach will be essential to achieve a design of the new units that are "reasonable" taking into account economic and social situations.

Training and education of personnel in radioprotection is greatly increased by the implementation of radioprotection university courses. This enables a presence of radiation protection engineers in the field, able to interact with their colleagues in operations and to guide managerial choices taking into account the requirements of radiation protection. The training of staff should also ensure the application of RP instructions, but must also allow stakeholders to govern unexpected situations.

The continuation of the benchmark and the exchanges between utilities and authorities, but also the mutualisation of analyses has to develop. Since 1992, the ISOE network constitutes unmistakably a big success example by creating real one community including the utilities RP staff and the authorities.

CHALLENGES

Aging facilities require maintaining the productive capacity, major works which will significantly increase. This increase in volume of maintenance could be very large, for example, in France; this increase of work time is estimated to be up to 60 % for 2020, compared with 2012. The optimisation actions should reduce or at least limit this increase. Below different hypotheses selected by EDF are illustrated [3].

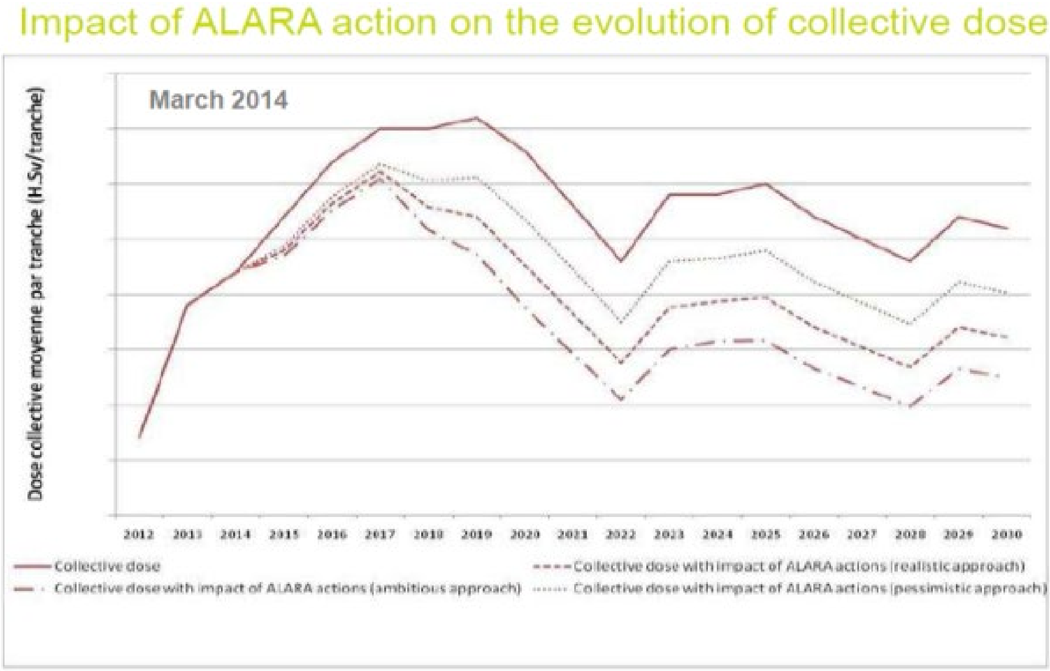


FIG. 5. Possible dose saving until 16% of the collective dose by implementing the main ALARA technical means (work monitoring, decon, shielding)

To this increase in the volume of maintenance must be added the modifications termed "Post Fukushima", although these modifications concern mainly tasks outside of the controlled area, with a minor direct impact on dose, even though some sensitive work such as strengthening the Fessenheim raft had a significant dosimetric cost (of the order of 100 man.mSv) was managed by a reinforced ALARA requirement. The allocation of resources dedicated to these changes should not occur at the expense of dose reduction actions.

The aging working populations have operated the nuclear fleet since the 1980s. The staffs who were hired at the start-up of the sites in the 1980s have reached the age of retirement, amongst the operators as well as the suppliers. The arrival of new personnel raises issues of training, this situation is temporary, but it is also an opportunity with these new arrivals to have a new look.

THE CONCEPT OF A "POST ALARA" APPROACH

A new management dynamic to maintain and support the desire to progress seems necessary, including in addition of the ALARA approach to take in account the human factor, the acute exposures risks, the individual dose management in cooperation with contractors and authorities.

This new dynamic is happening mainly by a dialogue between operators, contractors and authorities to anticipate and address the problems of radiation protection in one prevention aim, seeking to avoid a costly administrative drift in energy and therefore efficiency. Everyone must remain in his role, the responsibility for the results being carried by the operator. Risk analysis should be the starting point of any preventive measure.

Amongst the new nuclear staff, we observe "chronic anxiety" stemming largely from a lack of understanding of the level of risk associated with dose. It will be therefore necessary to provide answers to these fears through training adapted to each population, and also the means to demonstrate rigour and professionalism.

Progress in management for the limitation of individual doses: increasing the volume of maintenance will result in an increase in the collective dose, and also an increase in the number of staff exposed. The approach of individual dose control is therefore an achievable goal, but it will require the implementation of innovative approaches in the field of radiation protection, and also in the field of contracts between operators and service providers.

Progress in RP culture: The nuclear industry has achieved a satisfactory level of compliance with rules in the field of radiation protection, managerial involvement has been achieved through the implementation of the ALARA initiative since the late 80s, but to progress beyond, the radiation protection culture of all stakeholders is needed to further reduce the dose. Using the Bradley model [4] (Fig.6), used in the field of industrial safety, we can conclude that in the field of radiation protection, the first two steps have been achieved, while overall and the managerial objectives are to move towards an interdependent RP practice of risk prevention, via individual involvement.

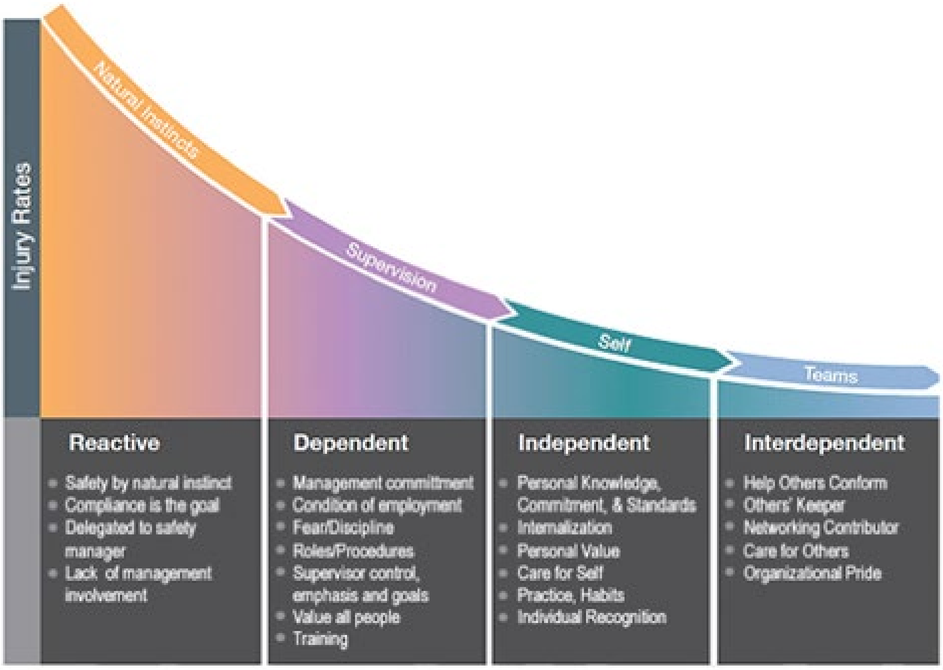


FIG. 6. Bradley model used in industrial safety

A comprehensive approach to risk: The field observation and analysis of feedback show that prevention measures to improve radiation protection and to reduce the likelihood of injuries at work are often identical. Sometimes, however, preventive measures are contradictory, such as when personal protective equipment against contamination induces a trip hazard, of impact by limiting visibility and of increased physical load. A search of all compensatory measures with regard to all risks should be conducted. Radiation / industrial safety risk assessments should therefore become increasingly common, for the nuclear industry to be exemplary in these two areas. The national regulatory developments push us in that direction, asking for a comprehensive consideration of risk.

Continue the process of reducing acute exposures risks. For example, industrial radiographic testing, which is not specific to the nuclear industry, but which is most frequently used, generates a risk of acute exposure for radiologists, and also for staff working nearby. Operators such as EDF set up organisations and technical measures to reduce this risk, but it is essential to continue with this approach. The IAEA published an experience sharing document under the ISEMIR network that enables everyone to question their practices and to self-asses [5].

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BRIEFING SESSION:

ACTIVITIES IN OCCUPATIONAL RADIATION PROTECTION AND MAIN CHALLENGES

Chairpersons: M. F. Webber, United States of America and P. Tattersall, United Kingdom

AN OVERVIEW OF THE IAEA ACTIVITIES ON OCCUPATIONAL RADIATION PROTECTION

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Abstract

Occupational radiation protection is one of the important programme in the radiation safety area in the International Atomic Energy Agency. The objective of the programme is to promote an internationally harmonized approach for optimizing occupational radiation protection for reducing radiation exposures in the workplaces, through developing safety standards and guidelines and providing assistance for the application of these standards and guidelines in the IAEA Member States. The achievements of the Action Plan for Occupational Radiation Protection which was launched by the IAEA and ILO together with other international organizations as the result of the first International Conference on Occupational Radiation Protection held in Geneva in 2002 was briefed, and future challenges in terms of development of safety standards, strengthening ALARA networks, radiation protection in NORM industries as well as education and training were highlighted.

INTRODUCTION

Twelve years ago, the IAEA and the International Labour Organization in cooperation with some other international organizations organized the first International conference on occupational radiation protection in Geneva. As the result of the Conference, an Action Plan for Occupational Radiation Protection was launched by the IAEA and ILO together with other international organizations. The Action Plan was approved by the IAEA Board of Governors in September 2003. Fourteen actions covering nine topic areas of occupational radiation protection were included in the Action Plan. To supervise the implementation of the Action Plan, a Steering Committee was created, which held five Steering Committee Meetings during the implementation of the Action Plan. Significant progress has been made in the area of occupational radiation protection since that time. It is important to introduce you the output of the IAEA's activities on occupational radiation protection.

ACHIEVEMENTS UNDER THE ACTION PLAN AND FUTURE CHALLENGES

There were a lot of achievements during the implementation of the Action Plan. The major accomplishments are:

- ILO No 115 Convention was successfully ratified and applied.
- Occupational Radiation Protection Appraisal Services (ORPAS) have been developed and implemented for Member States.
- As mentioned before, a large number of standards and guidance documents have been developed including guidance material and four safety reports, three TECDOCs have also been published.
- Three regional ALARA networks, one international network: ISEMIR, and the webpage for Occupational Radiation Protection Network (ORPNET) have been established.
- Three NORM symposia were supported and the corresponding proceedings were published.

Today, we can conclude that the setup of the Action Plan by the IAEA, in collaboration with the ILO based on the Geneva Conference's findings and recommendations, focused on improving occupational radiation protection is an effective strategy. The collaboration between the IAEA and the ILO and some other international organizations during the implementation of the action plan was successful. The working approach was effective and the Steering Committee played an important role. All the fourteen actions were completed and I am happy to announce that the Action Plan has successfully reached its objectives

What are the future challenges which await us?

- Developing guidance material on external and internal dosimetry in accordance with the new draft Safety Guide on Occupational Radiation Protection and providing for their application;
- Updating and developing the training packages on occupational radiation protection and providing training in the Member States;
- Developing guidance on NORM including uranium mining and radon at workplaces;
- Strengthening ALARA network activities;
- Assisting Member States with the application of the IAEA Safety Standards;
- Knowledge transfer to NPP embarking countries.

It is important to emphasize that the objective of the IAEA occupational radiation programme is to promote occupational radiation protection optimization through developing safety standards and guidelines with an internationally harmonized approach. At the same time, to provide assistance for the application of these standards and guidelines in the Member States. The development of radiation safety standards is a major task under the occupational radiation protection programme of the IAEA. More than forty documents have been developed since the Geneva Conference including one safety guide, eight safety reports, eight Technical Documents (TECDOCs) and seven proceedings.

Subsequent to the establishment of the BSS, development of adequate supporting guidance remains our top priority. A comprehensive Safety Guide on Occupational Radiation Protection is currently under development. The Safety Guide will follow the new BSS and the latest ICRP recommendations and will combine, update and supersede the existing five safety guides on occupational radiation protection. One of the specific issues in the area of occupational exposure is the protection and safety of itinerant workers.

A new Safety Report Series: Radiation Protection of Itinerant Workers has been developed and is currently under publication. It provides guidance on mobile skilful workforce who carries out job assignments at a various work locations even across borders. The seven posters on occupational radiation protection have been translated into French, Russian and Chinese.

Radiation protection on Naturally Occurring Radioactive Material (NORM) continues to pose many challenges as highlighted in the outcomes of the Geneva Conference. In the past few years, many guidance documents have been developed in this area. Recently, the IAEA published three safety reports on radiation protection in the rare earths industry, in the titanium dioxide industry and the phosphate industry.

A training package on radiation protection and management of radioactive waste in the oil and gas industry has been developed and training courses are provided to the Member States.

Four international symposia on NORM were supported by the IAEA for which proceedings were published including the NORM IV, Poland, 2004; NORM V, Spain, 2007, NORM VI, Morocco, 2010 and the NORM VII held last year in Beijing, China.

Networking is one important approach for enhancing occupational radiation protection. Currently, the OECD/NEA and the IAEA jointly operate the Information System on Occupational Exposure (ISOE), ISOE is a forum for experience exchange in occupational radiation protection in Nuclear Power Plants. the ISOE IAEA Technical Centre represents the non-OECD Member States with NPPs and successfully organized the ISOE International Symposium in 2009 and will organize the next series in 2015 in Rio de Janeiro, Brazil.

Following the principle of ISOE, the IAEA is developing the Information System on Occupational Radiation Protection in Medicine, Industrial and Research (ISEMIR). A preliminary web-based database for interventional cardiology has been developed and the one for industrial radiography is under development.

The development for the information system on occupational exposure in uranium mining also has been initiated. Based on the expert meetings and the questionnaire survey, occupational exposure data from more than 80% percent of the uranium mining industry has been collected.

A webpage ORPNET: Occupational Radiation Protection Network has been created to facilitate the information exchange on occupational radiation protection. It provides a focal point for exchange of information through networking.

Regional ALARA networks are also an effective way how to facilitate the radiation protection optimization in different regions. Currently, the IAEA supports the following regional networks: ARAN: Asian Region ALARA Network; RECAN: Regional East European and Central Asian ALARA Network; and REPROLAM: Latin American Regional ALARA Network.

With the support of the IAEA, many activities have been conducted under the framework of the regional ALARA networks.

Maintaining the sustainable development of current networks and to create new networks in the Middle East and Africa regions are the challenges for the ALARA networks.

The Occupational Radiation Protection Appraisal Services (ORPAS) is an important service from the IAEA to Member States. The service is provided upon request from the Member States and focuses on end users and services providers. The key objective of the appraisals is to provide the host country with an objective assessment of the provisions for occupational radiation protection. So far, the guidelines and the questionnaire for ORPAS have been updated and six ORPAS missions have been conducted to the Member States.

The IAEA provides assistance for the application of Safety Standards in Member States. Occupational radiation protection is a milestone for providing services to the Member States. Under the IAEA technical cooperation framework, about fifty regional and national projects related with occupational radiation protection are being implemented through the activities of technical assistance, information exchange, education & training, and appraisal services. More than ten regional training courses and workshops are held every year. Country profiles on occupational radiation protection are reflected in the Radiation Safety Management System (RASIMS) of IAEA.

CONCLUSIONS

Significant progress has been made in occupational radiation protection worldwide since the Geneva Conference. This is the result of cooperation between the IAEA, Member States and other international organizations; as well as the result of considerable efforts of all stakeholders for occupational radiation protection. Despite the achievements, we are still facing challenges; it is the responsibility of the whole international community to continue making improvements in enhancing the protection of workers.

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ILO ACTIVITIES ON OCCUPATIONAL RADIATION PROTECTION

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Abstract

The International Labour Organization (ILO) has as one of its prime tasks the protection of workers against sickness, disease and injury arising from employment. The development of international standards in the form of Conventions and Recommendations is one of the main functions of the ILO. These standards constitute the International Labour Code which defines minimum standards in the labour and social fields. The ILO Conventions are a powerful mechanism in international law, which motivates states to implement and demonstrate safety and health provisions complying with current international standards. Between 1919 and 2014, 189 Conventions and 203 Recommendations were adopted. Close to 50 per cent of these instruments relate directly or indirectly to occupational safety and health. Convention No. 115 and Recommendation No. 114 deal specifically with the protection of workers against radiation (ionizing). ILO works with its constituents and with other organizations to promote the application of the ILO Convention No. 115 in its member States.

INTRODUCTION

Distressing images of accidents have the effect of attracting the attention of the mass media, at the same time provoking immediate reactions from the politicians and the public. This is particularly true in recent years with a number of devastating large-scale accidents such as the Fukushima NPP accident, the Bangladeshi Rana Plaza building collapse which killed 1,138 workers, the Garment factory fire in Pakistan which killed hundreds of workers, and the Texas fertilizer plant explosion which killed 15 and injured 160.

As a response to the decline in workplace safety and health, in their 2013 St Petersburg Declaration, the G20 leaders requested the Group's task force to partner with the ILO to consider how the G20 might contribute to a safer workplace. They also called for achieving the highest possible level of nuclear safety and nuclear security culture. The G20 leaders renewed their call for workplace safety and health when they met in Brisbane, Australia in September 2014 and requested in their communiqué that the improvement of workplace safety and health be a priority.

Occupational accidents and work-related diseases cause over 2.3 million fatalities per year, of which over 350,000 are caused by occupational accidents and close to 2 million through work related diseases. There were also over 313 million non-fatal occupational accidents in 2010 (requiring at least four days of absence from work), signifying that occupational accidents provoke injury or ill-health for approximately 860,000 people every day. The use of radioactive sources involves risks due to radiation exposure. Exposure to ionizing radiation occurs in many occupations. When protection is inadequate or has failed, exposure to ionizing radiation can cause acute injuries, diseases and even deaths.

Radiation protection is part of the ILO's action on the protection of workers against sickness, disease and injury arising out of employment, as mandated by the Organization's Constitution.

The development of international standards in the form of Conventions and Recommendations is one of the main functions of the ILO. These standards, which are adopted by the International Labour Conference covers labour and social issues. As a package, they constitute the International Labour Code which defines minimum standards in the labour and social fields. Between 1919 and 2014, 189 Conventions and 203 Recommendations were adopted. Close to 50 per cent of these instruments relate directly or indirectly to occupational safety and health.

In June 1960, the International Labour Conference adopted the Radiation Protection Convention, 1960 (No. 115) [1], and its accompanying Recommendation No. 114 [2]. This Convention has been ratified by 50 countries. A most recent ratification was in May 2013 by Lithuania. The Convention applies to all activities involving the exposure of workers to ionizing radiation in the course of their work and provides that each Member of the ILO which ratifies it shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate means. So far, this ILO Convention has been the only international legal instrument on the protection of workers against radiation.

There are a number of instruments which establish the general framework and institutional arrangements for the protection of workers against occupational hazards in general [3-7]. These are also relevant to the radiation protection of workers. In particular, there are the Occupational Safety and Health Convention (No. 155) and Recommendation (No. 164) concerning occupational safety and health and the working environment, adopted in 1981 and laying down for the first time at the international level the foundations of a national policy branching out to undertakings, in order to introduce a comprehensive and coherent system of prevention of occupational hazards. Convention (No. 161) and Recommendation (No. 171) concerning occupational health services, adopted in June 1985, provide for the establishment of occupational health services which should progressively be developed for all workers in all branches of economic activities. These instruments cover, in particular, the functions, organization and conditions of operation of such services.

A basic principle expressed in Convention No. 115 and Recommendation No. 114 is that the exposure of workers to ionizing radiations shall be reduced to the lowest practicable level and that any unnecessary exposure should be avoided. Other requirements stipulated in Convention No. 115 include keeping dose limits for various categories of workers under constant review in the light of current knowledge and with “due regard” to the relevant international recommendations; fixing specific dose limits for different categories of workers, including workers aged 18 and over, workers under the age of 18, and workers not directly engaged in radiation work; and prohibiting workers under the age of 16 from working with ionizing radiations. A major contribution by the ILO to radiation protection is the promotion of the right of workers to safety and health while working with radiation, which includes participation, employer and worker cooperation, training and information.

Driven by a common interest to allow resources to be used effectively and prevent duplication of efforts, as well as to create synergy and maximize the impact of the relevant standards formulated separately by individual organizations, collaborations for internationally harmonized standards have been on the increase since the early 1960s. The ILO attaches importance to cooperation with other international organizations on the protection of workers against radiation through joint development and the preparation of international standards and guidance.

An important outcome of the international cooperation in the field of radiation safety and protection has been the development of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), which build on earlier international recommendations by the International Commission on Radiological Protection (ICRP). The BSS are co-sponsored by the Food and Agriculture Organization of the United Nations (FAO), the IAEA, the ILO, the Nuclear Energy Agency of the Organisation for Economic Co-operation and Development (OECD/NEA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO), and were formally published in 1996. This BSS was revised and published in the summer of 2014. The ILO participated in the revision process and the Governing Body of the ILO at its 313th Session authorized the revised BSS to be published as a joint publication. The BSS provides a worldwide basis for harmonized radiation protection standards that complement ILO Convention No. 115. All the sponsoring organizations of the BSS have worked closely in the harmonization and development of international standards and policies on radiation protection and safety, and have promoted the application of the BSS in their own fields of competence. Operations undertaken with the assistance of one of the other co-sponsoring organizations apply the BSS in the light of the relevant rules and regulations of the particular organization concerned. For the ILO, the BSS is used to support the implementation of Convention No. 115 and guide those whose duty it is to promote protection against occupational exposure to radiation at the national and enterprise levels. The BSS is also used by the ILO supervisory machinery to review and examine the application and implementation of Convention No. 115 and Recommendation No. 114 by member States.

To help the application of the BSS, the ILO, the IAEA and other international organizations have jointly prepared a number of international guides which include guidance on: protecting against occupational exposure to radiation in general; assessing occupational exposure, whether internal or external; protecting workers against radiation in the mining and milling of radioactive ores; controlling exposure to natural radiations at work; protecting emergency workers; monitoring the health of persons exposed to ionizing radiation at work; and protecting against radiation in hospitals and general practices. The documents which the ILO is contributing to and collaborating on include IAEA's Safety Requirement Part 7 - Preparedness and response for a nuclear or radiological emergency, Safety guide on occupational radiation protection, training material for occupational radiation protection during emergency operations, guidelines for industrial safety management for nuclear power plants, guidance on occupational radiation protection during decommissioning of nuclear power plants and research reactors. The ILO is participation in the work of the International Technical Advisory Group on the IAEA's World Report on Fukushima Nuclear Power Plant Accident.

Together with other UN agencies, the ILO has actively taken part in the work of the Radiation Safety Standards Committee (RASSC) established by the International Atomic Energy Agency (IAEA). RASSC is vested with the important mission of reviewing the Agency's Safety Series documents on radiation protection and safety of radiation sources and the Agency's programme of work for the preparation of these documents. The ILO's participation in the RASSC ensures that employers' and workers' representatives and organizations participate directly in the formulation by the IAEA and other international organizations of international standards on radiation safety and on protection against occupational exposure to radiation.

Collection and dissemination of information is a major means of action of the ILO as regards occupational safety and health. A global database on occupational safety and health legislation is being built. The Information Note on Radiation Protection of Workers prepared soon after the 2011 Fukushima NPP Accident provides a summary of the relevant ILO documents and publications relevant to radiation protection and emergency preparedness and response. The

ILO has also had a number of other means of disseminating information such as the publications in its Occupational Safety and Health Series a latest example is OSH No 73 (Approaches to attribution of detrimental health effects to occupational ionizing radiation exposure and their application in compensation programmes for cancer) and the organization of scientific and technical meetings, congresses or symposia. The ILO also collaborates and cosponsor international conference on radiation protection organized by the other international organizations and by the other international professional bodies. Currently, the ILO is collaborating in the organization of the IAEA International Conference on Global Emergency Preparedness and Response from 19-23 October 2015 in Vienna, Austria and the 14th International Congress of the International Radiation Protection Association which is to take place from 9-13 May 2016 in Cape Town, South Africa.

The ILO organizes technical cooperation activities to protect the life and health of workers which are very wide, ranging from the technical back-stopping of the regional, area and country office and of the technical departments at the headquarters, and the provision of experts to study particular problems or the award of grants for study and further training, to the setting up of occupational safety and health institutes, centres or laboratories, providing the necessary equipment and training of staff.

The current activities of the ILO are centred on the promotion of the active involvement of employers' and workers' organizations in occupational radiation protection and the implementation of the BSS and the Safety Fundamentals at both international and national levels. At the international level, the ILO supports and organizes the involvement of the representatives of the International Trade Union Confederation (ITUC) and the International Organization of Employers in the work of IAEA's Radiation Safety Standards Committee (RASSC). The ILO is a member of the Inter-agency Committee on Radiation safety (IACRS) and participates, together with other member organizations in the discussions of international policies and standards on radiation protection and in the coordination among themselves radiation protection activities carried out by individual member organizations. The ILO participates in the work of the Committee on Radiation Protection and Public Health (CRPPH) of the OECD/NEA and the Global Initiative on Radiation Safety in Health Care Settings of the WHO.

The ILO maintains close links with international scientific communities, in particular with the ICRP, whose work is a primary basis for the development of international standards on radiation. For example, the ILO contributed to the work of the ICRP and its task groups on the development of documents related to occupational exposure. In assessing compliance with these requirements, the Committee of Experts on the Application of Conventions and Recommendations (CEACR) has frequently referred to current knowledge as embodied in relevant international standards and has developed principles in particular as regards the purpose and function of the dose limits, including exposure limits during and after an emergency and the provision of alternative employment to workers whose continued working with radiation is contra-indicated for health reasons. The General Observation adopted and published in 1992 at the 79th International Labour Conference has been a major tool for the work of the Committee of Experts on the Application of Conventions and Recommendations which is charged with examining the application of ILO Conventions and Recommendations by ILO member States. This General Observation was based on ICRP recommendation 60 and the previous BSS. ILO is intending to collaborate with ICRP and IAEA to revise this General Observation so that it can be based on ICRP 103 and the newly revised BSS.

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A COLLECTIVE PERSPECTIVE

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Abstract

The Nuclear Energy Agency assists its member countries, currently 31 countries from Europe, North America and the Pacific area, in maintaining and further developing the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes. A brief outline of the NEA's activities in the field of occupational radiation protection and its involvement and cooperation with other international organizations are provided.

INTRODUCTION

In 2002, when the first international conference on occupational radiation protection was held in Switzerland, NEA welcomed the participants as one of the conference co-operating organisations. Twelve years have passed and to share the NEA's vision in the field of occupational radiation protection, the organisation continues to support the objective of this international conference and will contribute to enhancing worker safety. Referring to the International Action Plan of Occupational Exposure, established by the first international conference, the NEA has participated in the Steering Committee for its implementation, and see clear pathway through the conference for future improvements in the field of occupational radiation protection.

The Nuclear Energy Agency assists its member countries, currently 31 countries from Europe, North America and the Pacific area, in maintaining and further developing the scientific, technological and legal bases required for a safe, environmentally friendly and economical use of nuclear energy for peaceful purposes, and to provide authoritative assessments and to foster common understandings on key issues. The technical programme of the agency overseen by the Steering Committee for Nuclear Energy is supported by seven standing technical committees, including the Committee on Radiation Protection and Public Health (CRPPH) [1]. The Committee's participants are policy makers, regulators representatives of research and developments institutions and relevant international organisations. The Committee's focus is on emerging radiological protection issues, and on the exchange of experience. Through its efforts, CRPPH is helping to establish a sustainable regulatory programme for nuclear power and waste management operations that is also applicable to medical, research and other industrial uses of ionising radiation.

Within this broad scope, the specific work of the CRPPH has included:

- Addressing and learning from the issues arising from the Fukushima Daiichi accident, particularly decontamination, stakeholder involvement, and living in contaminated area aspects;
- The evolution and implementation of the system of radiological protection, providing input to the ICRP on draft recommendations, and to the IAEA on draft versions of Safety Requirements documents;

- The state-of-the-art in radiological protection science and its implications for radiological protection policy, regulation and implementation. In particular the CRPPH will study the variability of an individual's dose with age, gender and body-shape;
- Science and values aspects of radiological protection decision making, and of stakeholder involvement aspects and approaches; and
- Emergency and recovery management planning and implementation issues and experience.

The majority of relevant work of the CRPPH for this conference has addressed operational radiological protection issues, through two groups. The Expert Group on Occupational Exposure (EGOE) developed, over the past 7 years, three case study reports that addressed: Occupational radiation protection (ORP) principles for the design of new plants; understanding and use of dose constraints; and the management of outside workers and integrated risk management. The collective message of this group of reports are given below in some detail:

ORP PRINCIPLES AND CRITERIA FOR DESIGNING NEW NPPS

There is a need to consider full life-cycle at the design stage (e.g. through available feedback from maintenance and dismantling) and to organize training and knowledge management through extended life-cycle (2-3 generations of workers). Networking is an important element to enable information collection and exchange on ORP during design and over full life-cycle.

DOSE CONSTRAINTS IN ORP: REGULATIONS AND PRACTICES

Implementation of dose constraints depends on co-operation between registrant, licensee and regulator and use of dose constraints limits the inequity of exposure vs. unequal individual exposure may sometimes be justified and radiation exposure is not always the only or predominant workplace risk with individual approaches, often not only a single value, but a set of numerical criteria (e.g. individual dose, collective doses, ambient dose rate, etc. embedded in a decision flow chart).

MANAGEMENT OF OUTSIDE WORKERS AND INTEGRATED RISK MANAGEMENT

- International outside workers work in a heterogenic legal environment and has to cope with conflicts from regulatory inconsistencies between the different countries involved. Regulations and monitoring practices often differ between countries, although there exist generally acknowledged ICRP recommendations.
- The simultaneous consideration of multiple contributors to risk to workers and the public is a complex undertaking and development of flowcharts and/or procedures which address all of the relevant factors and quantify all of the elements of balanced decision-making is more complex and is potentially impractical for some facilities and situations.
- Integrated risk management will always remain in development with scientific understanding of risks and their interactions improve with time, techniques for work performance evolve with time and technology and society's perspectives on risk are dynamic.

The Information System on Occupational Exposure (ISOE) programme, cosponsored by the IAEA, has worked since 1992 to collect occupational exposure collective dose data from nuclear power plants, and to foster the exchange of operational worker exposure management experience. The recent ISOE expert group report, Occupational Radiation Protection in Severe Accident Management focuses on RP management and organization, training and exercises related to severe accident management, facility configuration and readiness, worker/responder protection, monitoring and managing radioactive releases and contamination and key lessons learned especially from the TMI, Chernobyl and Fukushima Daiichi accidents will be introduced and discussed in the relevant session of this international conference

Finally, the conference will help to guide the future work of the NEA in the field of occupational radiation protection.

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WHO ACTIVITIES RELATED TO OCCUPATIONAL RADIATION PROTECTION

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Abstract

The World Health Organization (WHO) has important role in improving public health. As part of its radiation programme, WHO closely cooperates with other international organizations in the field of radiation protection of workers. This briefing note outlines some of the activities carried out during the past decade since the first international conference on occupational radiation protection.

INTRODUCTION

Twelve years have passed since the First International Conference on Occupational Radiation Protection (ORP) that was held in Geneva. It was jointly convened by the International Atomic Energy Agency (IAEA) and the International Labour Organization (ILO), cosponsored by the European Commission (EC) in cooperation with the OECD Nuclear Energy Agency (NEA) and the World Health Organization (WHO), under the theme “Protecting workers against exposure to ionizing radiation”. We are all here today at this Second International Conference on ORP jointly convened by the IAEA and ILO, in cooperation with 15 international organizations including WHO, under the theme “Enhancing the protection of workers-gaps, challenges and developments”. This communication summarizes some relevant activities done by WHO during these 12 years. WHO has participated in the international action plan on ORP (IAPORP) established by IAEA in cooperation with ILO and other relevant international organizations as a result of that first conference. As a member of the Steering Committee WHO contributed to the IAPORP formulation and implementation, in particular for: Action 9 related to postgraduate education and awareness-raising packages for medical professionals; Action 10 concerning the update of a manual on radiation protection for health workers; Action 14 on guidance for aiding decision-making on the attribution of cases of detrimental health effects to occupational exposure to ionizing radiation for compensation purposes. The major output of this action was the report entitled "Approaches to attribution of detrimental health effects to occupational IR exposure, and their application in compensation programmes for cancer – a practical guide", cosponsored by ILO, IAEA, WHO [1].

WHO RADIATION PROGRAMME

During the same period, the international basic safety standards (the BSS) have been revised. The new standards co-sponsored by the EC, IAEA, ILO, FAO, OECD/NEA, PAHO, UNEP and WHO were recently published [2]. The new BSS, that represent the international benchmark for radiation safety, include a section on occupational exposures providing safety requirements for protecting workers from exposure to ionizing radiation. In line with its core functions, WHO has cooperated with the other international organizations in the BSS revision process, has adopted the new BSS in 2012 and is currently cooperating with all cosponsors to support the BSS implementation. A Task Group on BSS Implementation was established within the Inter-Agency Committee on Radiation Safety (IACRS) and a strategic plan has been developed, including the provisions of safety guides, training packages, information materials (e.g. brochures, posters, leaflets) as well as regional and national BSS workshops. WHO is conducting the Radiation Programme covering different scenarios, where human exposure to ionizing radiation takes place, including planned, existing and emergency exposure situations. These scenarios comprise radiation exposure at workplaces. For instance, the WHO Global Initiative on Radiation Safety in Health Care Settings addresses ORP of health workers. The Bonn Call for Action was the main outcome of the International Conference on Radiation Protection in Medicine organized by the IAEA and cosponsored by WHO [3]. It identified ten priority actions to improve radiation protection in medicine in the next decade and it encompasses ORP of health workers. WHO conducted the WHO Radon project initially focused on prevention and mitigation of radon exposures of members of the public (i.e. radon in dwellings); the current WHO radon programme also addresses occupational exposures to radon and NORM. WHO has contributed to the UN Action Plan for the third decade of Chernobyl through implementation of the Inter-Agency project "Human Security for Individuals and Communities in Chernobyl-affected Areas through Local Information Provision" (ICRIN), jointly conducted by the IAEA, UNDP, UNICEF and WHO. The aim of the project was to provide accurate, up-to-date, and reliable information to people living in Chernobyl-affected areas including members of the public and former liquidators. WHO continues participating in the Inter-Agency Task Group on Chernobyl, currently discussing priorities and future strategy for the post-2016 period. WHO response to the Fukushima Daiichi NPP accident required addressing issues related to radiation exposure and associated health risks in both workers and members of the public. The WHO response actions and the public health agenda were summarized in a paper published in early 2012 [4]. WHO conducted a health risk assessment from the Fukushima Daiichi nuclear accident that covered general population from inside and outside Japan as well as emergency workers that was published in early 2013 [5]. More recently WHO published a general framework for radiation-related cancer risks in workers and members of the public from the 2011 Fukushima nuclear accident [5].

In the framework of the WHO Radiation Programme, a mechanism for collaboration with other relevant WHO programmes is in place to coordinate actions, promote synergies and avoid duplication of efforts. This includes cooperation with the WHO Occupational Health Programme which is supporting the implementation of the WHO Global Plan of Action on Workers' Health 2008-2017 endorsed by the World Health Assembly in 2007. The WHO Global Occupational Health Network (GOHNET) supports its implementation by addressing primary prevention of occupational hazards, protection and promotion of health at work, improvement of employment conditions and better response from health systems to workers' health under seven common principles:

- All workers should be able to enjoy the highest attainable standard of physical and mental health and favourable working conditions.
- The workplace should not be detrimental to health and wellbeing.
- Primary prevention of occupational health hazards is a priority.
- All components of health systems should be involved in an integrated response to the specific health needs of working populations.
- The workplace can also serve as a setting for delivery of other essential public-health interventions, and for health promotion.
- Activities should be planned, implemented and evaluated with a view to reducing inequalities in workers' health within and between countries.
- Workers, employers and their representatives should participate.

WHO is currently working on the integration of occupational radiation protection into the global occupational health agenda and, in this context, a Special Session will be jointly conducted by ILO, WHO and ICOH at the next International Congress of Occupational Health ICOH2015 [7], where the conclusions and recommendations of this Second International Conference on ORP will be presented.

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TOPICAL SESSION 1:

INTERNATIONAL RECOMMENDATIONS AND STANDARDS ON OCCUPATIONAL RADIATION PROTECTION: RECENT CHANGES AND CHALLENGES IN THEIR PRACTICAL IMPLEMENTATION

Chairpersons: I. Lund, Sweden and S. H. Na, Republic of Korea

OCCUPATIONAL RADIATION PROTECTION – STABILITY AND CHALLENGES IN VIEW OF THE IAEA BASIC SAFETY STANDARDS

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Abstract

The role of the IAEA is to establish fundamental safety objectives in radiation protection and safety following fundamental safety objectives, safety principles and concepts. The main aim of the Safety Standards is to provide for the establishment of a system for protection of people and the environment from harmful effects of ionizing radiation. The requirements as included in the Safety Standards aim to assess, manage and control exposure to radiation so that radiation risks, including risks of health effects and risks to the environment, are reduced to the extent reasonably achievable. The article briefly introduces several selected principal features of the revised BSS, like for example format of the BSS, categorisation of requirements according to the exposure situations, responsibility of individual parties for protection and safety and dose limits.

INTRODUCTION

According to IAEA Statute [1] the IAEA is authorized "[…] to establish or adopt, in consultation and, where appropriate, in cooperation with the competent organs of the United Nations and with the specialized agencies concerned, standards of safety for protection of health and minimization of danger to life and property… to any of State's activities in the field of atomic energy." Along with this statutory obligation, the IAEA in cooperation with EC, FAO, ILO, NEA, PAHO, UNEP and WHO undertook the revision of the General Safety Requirements Part 3: Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (BSS) [2]. The BSS serves as a regulatory standard that may be directly used, transferred or adopted into regulatory systems of Member States of the IAEA. The revised BSS maintains as the fundamental pillars of the radiation protection the concepts of justification of practices, optimization of protection and application of dose limits; and focuses on optimization and integration of radiation protection within modern concepts and approaches to risk management.

The revised BSS also addresses areas like exemption and clearance being particularly important in international trade and transport; significantly increases the number of requirements in medicine, in response to novel and/or expanding techniques in medicine using ionizing radiation; incorporates new regulatory limits for exposure to radon, and in protection of the lens of the eyes, as recommended by WHO and ICRP; newly introduces requirements for specific practices like, for example, airport security screenings; and addresses many other areas.

While the principal approach to regulatory aspects in emergency exposure situation has not been significantly modified from the previous BSS version, the revised one, for example, strengthens the protection of emergency workers by setting the maximal dose that can be received during emergency response, and by putting emphasis on the principle of voluntary action in certain circumstances. The need for scientifically sound, administratively and legally recognized, and also practical and applicable regulations in emergency situations has also been recently surfacing in the view of Fukushima NPP accident.

The BSS is based on fundamental safety objectives in radiation protection and safety as are stated in the IAEA Safety Fundamental Principles (SF1) [3] – the principal IAEA radiation protection and safety publication, which establishes the fundamental safety objectives, safety principles and concepts that provide the bases for the IAEA's safety standards (including BSS) and for the IAEA safety related programme. The main aim of the SF1, as well BSS, is to provide for the establishment of a system for protection of people and the environment from harmful effects of ionizing radiation. Thus, the requirements as included in the BSS aim to assess, manage and control exposure to radiation so that radiation risks, including risks of health effects and risks to the environment, are reduced to the extent reasonably achievable.

THE FORMAT OF THE REVISED BSS

The BSS presents two types of requirements: Umbrella/Overarching Requirements and Associated Requirements. Umbrella/Overarching Requirements state the general obligations to be met, and these are further specified in subsequent Associated Requirements. All requirements, either Umbrella/Overarching Requirements or Associated requirements are written as "shall statements", carry an equal level of obligation, and are written in the style - "who shall do what". In addition to requirements there are paragraphs of Scope, which describe the circumstances to which the requirements of the given Chapter or Section apply, and paragraphs of Introduction, which do not establish obligations.

Further, each exposure situation section is organized into generic requirements and those specifically applicable in occupational, public, and medical exposures as appropriate. The following structure is adopted:

- Introduction: Descriptive and explanatory section covering principles and concepts. It explains categorization into planned, emergency and existing situations, and three categories of exposure (public, occupational, medical). It provides brief explanation of scientific background, principles of justification, optimization, dose constraints and reference levels, and dose limitation, and also describes the approach to protection of the environment.
- General requirements for protection and safety: Contains requirements applicable to all exposure situations and covers requirements directed at governments, regulatory bodies, and other responsible parties. It also deals with education, training and competence.

- Planned exposure situations: comprises of requirements for planned exposure situations, which are further grouped into requirements in occupational, public and medical exposures.
- Emergency exposure situations: Requirements in this section are directed to activities in emergency preparedness and response to a nuclear or radiological emergency, including requirements for occupational and public exposures.
- Existing exposure situations: Set of requirements directed to handling existing exposure situation, i.e. situations that already exist when a decision on control has to be taken; these are typically situations for controlling radon exposure, exposure to radionuclides in commodities, exposure to cosmic radiation and exposure to cosmic radiation. Requirements for both occupational and public exposures are included.
- Four Schedules providing additional requirements for specific cases: Exemption and clearance, categorization of sources, dose limits for planned exposure situations, and criteria for emergency preparedness and response.

In comparison with the previous edition (BSS 1996) [4] was organized into principal requirements and detailed requirements having the similar function as (Umbrella or Overarching) Requirements and Associated Requirements of the revised BSS, respectively. However, there is neither direct link between Principal and (Umbrella or Overarching) Requirements, nor between Detailed and Associated ones. In the BSS 1996, the Principal Requirements were drafted and grouped together into standalone set of requirements establishing the "complete" set, (Chapters I, II and III). The Detailed Requirements were written as Appendices. Further, not every paragraph of the BSS 1996 is written in the style "who shall do what", and instead it is written in the general form "something shall be done", leaving flexibility for executive bodies to assign such responsibility.

As such, the (Umbrella or Overarching) Requirements of the revised BSS shall not be read in isolation from Associated ones, because they do not, and were not intended to, represent comprehensive set of requirements satisfying the required level of safety.

Another difference between the revised BSS and the BSS 1996 is the following: While the BSS 4.0 follows the responsibility line : Government → Regulatory body → Other parties (principal and other parties), established in Chapter 2, with each and every paragraph (except Scope ones) stating and assigning responsibility as written above; in the BSS 1996 the responsibilities of Government and Regulatory body are described in general form in the Preamble, and Principal and/or Associated requirements in individual Chapters or Appendices, respectively, are directed mostly to Registrants and licensees.

Both, the revised BSS and the BSS 1996 contain Schedules, providing further detail requirements. Paragraphs of Schedules are all "shall" statements and represent same level of obligation as paragraphs in the main text.

CATEGORISATION OF REQUIREMENTS ACCORDING TO THE EXPOSURE SITUATION

One of the novel features adopted in the revised BSS is the classification of exposures, which follows the ICRP Publ.103 (ref.), i.e. it categorizes exposures into three exposure situations (planned, emergency and existing), each of them including several categories of exposure (occupational, public and medical), where appropriate (Fig.1)

Type situation - source related	Category - activity related
Planned exposure situations	Occupational exposure Public exposure Medical exposure
Emergency exposure situations	Exposure to emergency workers Public exposure
Existing exposure situations	Occupational exposure Public exposure

FIG. 1. Exposure situations and category of exposure.

The BSS also addresses areas like Exemption and Clearance – the issue being particularly important in international trade and transport; significantly increases the number of requirements in medicine, in response to novel and/or expanding techniques in medicine using ionizing radiation; incorporates new regulatory limits for exposure to radon, and in protection of the lens of the eyes, as recommended by WHO and ICRP; newly introduces requirements for specific practices like, for example, airport security screenings; and addresses many other areas.

While the principal approach to regulatory aspects in emergency exposure situation has not been significantly modified from the previous BSS version, the revised one, for example, strengthens the protection of emergency workers by setting the maximal dose that can be received during emergency response, and by putting emphasis on the principle of voluntary action in certain circumstances.

The need for scientifically sound, administratively and legally recognized, and also practical and applicable regulations in emergency situations has also been recently surfacing in the view of Fukushima NPP accident.

RESPONSIBILITY FOR PROTECTION AND SAFETY

The revised BSS follows the responsibility line: Government → Regulatory body → Other parties (principal and other parties), which is established in Chapter 2, (Fig.2).

The BSS 1996 describes the responsibilities of Government and Regulatory bodies in general form in the Preamble. Principal and/or Associated requirements in individual Chapters or Appendices, respectively, are directed mostly to Registrants and licensees.

Responsibility to establish and maintain a legal, regulatory and organizational framework
- ➢ Government (Requirement 2)

- Responsibility to establish or adopt regulations and guides
  - ➢ Regulatory body (Requirement 3)

- Prime responsibility
  - ➢ Person or organization responsible for facilities and activities (Requirement 4)
  - ➢ Principal parties (paragraph 2.40*)
    *Specified responsibility
  - ➢ Other parties (paragraph 2.41)

FIG.2. Allocation of responsibility for the protection and safety.

DOSE LIMITS

The BSS clearly assigns the responsibility for the establishment of dose limits for planned exposure situation to the government or the regulatory body for occupational exposure and public exposure, while the responsibility for applying dose limits is assigned to registrants and licensees.

Dose limits are not changed from the BSS 1996 and follow the ICRP recommendation (ref.) (Table 1).

TABLE 1. DOSE LIMITS FOR PLANNED EXPOSURE SITUATIONS

Exposure	Occupational exposure		Public exposure
	Over 18 years of age	16 to18 years of age	
Whole body	20 mSv averaged over 5 years max 50 mSv in a single year	6 mSv	1 mSv In special circumstances a higher value (provided the average effective dose over five consecutive years does not exceed 1 mSv per year)
Lens of the eyes	20 mSv averaged over 5 years max 50 mSv in a single year	20 mSv	15 mSv
Skin, extremities	500 mSv	150 mSv	50 mSv

CONCLUSIONS

The revised BSS is the high-level IAEA document, which based on international consensus, may contribute to the high level of safety for protection of people and the environment from harmful effects of ionizing radiation through its implementation in national legislation frameworks. The importance of the BSS is strengthened also through outreaching of the role of specialized international bodies and agencies cosponsoring organizations (FAO, IAEA, ILO, NEA, PAHO, WHO, EC and UNEP) in revision process and in implementation of the BSS.

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THE NEW EURATOM BASIC SAFETY STANDARDS DIRECTIVE

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Abstract

With the publication of new basic safety standards for the protection against the dangers arising from exposure to ionising radiation, foreseen in Article 2 and Article 30 of the Euratom Treaty, the European Commission modernises and consolidates the European radiation protection legislation. A revision of the Basic Safety Standards was needed in order (i) to take account of latest scientific findings, technological progress, and operational experience since 1996 and (ii) to consolidate the existing set of EURATOM radiation protection legislation, merging five Directives and upgrading a recommendation to become legally binding. The new Directive offers in a single coherent document basics safety standard for radiation protection which takes account of most recent advances in science and technology, covers all relevant radiation sources, including natural radiation sources, integrates protection of workers, members of the public, patients and the environment, covers all exposure situations, planned, existing, emergency, and harmonises numerical values with international standards. After the publication of the Directive in the beginning of 2014, Member States of the European Union have four years to transpose the Directive into national legislation and to implement the requirements therein.

More information can be found at the link:

https://academic.oup.com/rpd/article/164/1-2/9/1603533

Modernisation and consolidation of the European radiation protection legislation: the new Euratom Basic Safety Standards Directive. Stefan Mundigl, Radiation Protection Dosimetry, Volume 164, Issue 1-2, April 2015, Pages 9–12, https://doi.org/10.1093/rpd/ncu285

REVISION OF THE INTERNATIONAL GUIDANCE ON OCCUPATIONAL RADIATION PROTECTION

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Abstract

The new International Basic Safety Standards (the BSS) published by the IAEA in 2014 sets out the requirements for occupational exposure for all types of situations involving exposure to ionizing radiation. To support the BSS, several guidance standards are under development. This paper outlines the revision of the guidance on occupational radiation protection that will be the major safety guide for protection of workers. The safety guide, prepared jointly by the IAEA and the ILO (International Labour Office), provides guidance on fulfilling the requirements of the BSS with respect to occupational exposure. It gives general advice on the exposure conditions for which radiation protection programmes (RPPs) need to be established, including the setting up of monitoring programmes to assess radiation doses arising from external radiation and from intakes of radionuclides by workers. It also gives more specific guidance on the assessment of doses from external sources of radiation and intakes of radioactive material. Additional new guidance on protection of workers in special cases such as female workers during and after pregnancy, itinerant workers, exposure to natural sources (radon at workplaces, NORM, cosmic ray exposure), protection of emergency workers, monitoring of the dose to the lens of the eye etc. are provided. This comprehensive draft safety guide updates and supersedes the five existing safety guides: Occupational Radiation Protection (IAEA Safety Standards Series No. RS-G-1.1), Assessment of Occupational Exposure due to Intakes of Radionuclides (RS-G-1.2), Assessment of Occupational Exposure due to External Sources of Radiation (RS-G-1.3), Occupational Radiation Protection in the Mining and Processing of Raw Materials (RS-G-1.6) and The Management System for Technical Services in Radiation Safety (GS-G-3.2). The draft is in an advanced stage of approval by the safety standards committee.

INTRODUCTION

— The International Safety Standards established by the IAEA

According to its statute, the International Atomic Energy Agency establishes safety standards for protecting people and the environment from harmful effects of ionizing radiation and provides support in its application in Member States. They are issued in the IAEA Safety Standards Series, which has three categories:

- Safety Fundamentals: These present the fundamental safety objective and principles of protection and safety, and provide the conceptual basis;
- Safety Requirements: Establishes a consistent set of requirements that must be met to ensure protection of people and the environment, both now and in the future; and
- Safety Guides: These provide recommendations and guidance on how to comply with the Safety Requirements, indicating an international consensus and reflect best practices, to help users to achieve high levels of safety.

A number of supporting publications on protection and safety are issued in other series and technical documents, in particular the IAEA Safety Reports Series.

— The International Basic Safety Standards

The International Basic Safety Standards (BSS) have been established by the IAEA from the year 1962 onwards and revised in 1967, 1982 and 1996 (BSS-115); which is now superseded by the new BSS titled, Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards, GSR Part 3, 2014 [1]. These revisions were in line with the widely accepted radiation protection and safety principles, established over the years, essentially through the recommendations of the International Commission on Radiological Protection (ICRP) and other IAEA Safety Standards. The new BSS are intended to ensure the safety of all types of radiation sources and were jointly sponsored by EURATOM, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP and WHO.

DEVELOPMENT OF THE SAFETY GUIDE ON OCCUPATIONAL RADIATION PROTECTION

— Revision process

Occupational exposure to ionizing radiation can occur in a wide spectrum of facilities and activities that include nuclear fuel cycle facilities, industries, medical institutions and educational and research establishments. Appropriate level of radiation protection of workers is essential for the safe and justified use of radiation, radioactive material and peaceful uses of nuclear energy. The IAEA reviews safety standards periodically to assess the need for their revision. This is accomplished through Member State feedback and various IAEA safety committees. With the establishment of the requirements for protection and safety in the BSS issued in 2014, three major safety guides have been planned to provide detailed guidance on how to meet those requirements for occupational, medical and public exposures. Accordingly, a document preparation profile was approved by the Commission on Safety Standards in 2011 to prepare a safety guide on occupational radiation protection – Draft Standard DS453 [2].

The safety guide, prepared jointly by the IAEA and the ILO, provides guidance on fulfilling the requirements of the BSS with respect to occupational exposure. It gives general advice on the exposure conditions for which radiation protection programmes (RPPs) need to be established, including the setting up of monitoring programmes to assess radiation doses arising from external radiation and from intakes of radionuclides by workers. It also gives more specific guidance on the assessment of doses from external sources of radiation and intakes of radioactive material. The draft safety guide reflects the current internationally accepted principles and recommended practices in occupational radiation protection, with account taken of the major changes that have occurred over the past decade. The new draft safety guide updates and supersedes the guidance given in five existing safety guides: Occupational Radiation Protection (IAEA Safety Standards Series No.RS-G-1.1), Assessment of Occupational Exposure due to Intakes of Radionuclides (IAEA Safety Standards Series No.RS-G-1.2), Assessment of Occupational Exposure due to External Sources of Radiation (IAEA Safety Standards Series No.RS-G-1.3), Occupational Radiation Protection in the Mining and Processing of Raw Materials (IAEA Safety Standards Series No.RS-G-1.6) and The Management System for Technical Services in Radiation Safety (GS-G-3.2).

Drafting groups comprising experts from the IAEA, the co-sponsoring organization ILO (International Labour Office) and external experts completed the first draft of the guide in 2013 followed by in-house and external reviews; this draft was then reviewed by the IAEA safety standards committees. Nearly 160 comments were received from the committee members. Taking these comments into account, a revised draft was completed in February 2014. This has been sent formally to all IAEA Member States for comment by June 2014. More than 600 written comments were received from 21 Member States and 3 organizations. The draft safety guide has been revised taking into account the comments and is currently under the review by the Safety standards committees. If approved, it is foreseen that the draft could be submitted to the Commission on safety standards (CSS) in the early 2015 for final approval and further to the IAEA Publication Committee.

— Scope, Objective and Structure of the new Safety Guide

The safety guide addresses the technical and organizational aspects of the control of occupational exposure. The recommendations given are intended primarily for regulatory bodies, employers, licensees and registrants; to management bodies and their specialist advisers; and to health and safety committees concerned with radiation protection of workers. The recommendations may also be used by workers and their representatives to encourage safe working practices. The basic structure of the revised safety guide on occupational radiation protection can be summarized as follows:

- Introduction;
- Framework for occupational radiation protection;
- Exposure of workers in Planned exposure situations:
  - Optimization;
  - Dose limitation;
  - Radiation protection programme;
  - Exposure of workers to natural sources.
- Exposure of workers in Emergency exposure situations:
  - Emergency planning and responsibilities;
  - Protection of emergency workers;
  - Managing the exposure of emergency workers;
  - Exposure assessment;
  - Medical attention.
- Exposure of workers in Existing exposure situations:
  - Protection strategies;
  - Justification, optimization;
  - Exposure arising from remedial actions in areas contaminated with residual radioactive material;
  - Exposure to radon;
  - Exposure to cosmic rays.
- Protection of workers in special cases;
  - Female workers during and after pregnancy;
  - Itinerant workers.
- Assessment of occupational exposure:
  - Assessment of external exposure;
  - Assessment of internal exposure;
  - Exposure assessment in emergencies;
  - Skin contamination;

    - Records of occupational exposure.
- Management system for providers of technical services:
    - Management responsibility, Process implementation;
    - Measurement, assessment and improvement;
    - Guidance for providers of calibration and testing services.
- Engineered controls, administrative controls and personal protective equipment:
    - Shielding, Ventilation, Dust control, Spillage of radioactive material;
    - Surface contamination, decontamination of equipment and personnel;
    - Personal protective equipment;
    - Job rotation;
    - Special considerations for mineral processing operations involving NORM.
- Workers' health surveillance:
    - Responsibilities;
    - Workers health surveillance programme;
    - Medical examination of workers;
    - Notification of ailments and over exposure;
    - Medical records;
    - Management of over exposed workers.

Five appendices and an annex provide additional, more detailed information relating to the exposure of workers to NORM, methods for individual monitoring for assessment of external exposure, workplace monitoring instruments for external exposure, monitoring and assessment of internal exposure (including biokinetic modelling), and techniques for retrospective dosimetry.

— Main changes

a) Terminologies and concepts

The draft safety guide provides guidance on fulfilling the requirements of the new BSS with respect to occupational exposure that is in line with the recommendations for a system of radiation protection developed by the ICRP [3]. These and other current recommendations of the ICRP and the International Commission on Radiation Units and Measurements (ICRU) have been taken into account in preparing this safety guide. In the framework for occupational radiation protection, the three exposure situations — planned exposure situations, existing exposure situations, and emergency exposure situations — in relevance to occupational exposure have been explained. It gives guidance on protection of workers in each of the three types of exposure situations and responsibilities of government, regulatory bodies and relevant parties. Guidance on the radiation protection principles — Justification, Optimization and Dose limitation are provided. Dose limits apply only in planned exposure situations. In such situations, the normal exposure to individuals should be restricted so that neither the total effective dose nor the total equivalent dose to relevant organs or tissues, caused by the possible combination of exposures from authorized practices, exceeds any relevant dose limit. The only change in dose limit is the equivalent dose to lens of the eye reduced from 150 mSv to 20 mSv. Guidance on the application of dose limits to occupational exposure is provided in Section 3 of the guide.

b) Existing exposure situations – Reference level

The concept of 'reference level' and its application in existing exposure situations are addressed in relevant section of the guide. In the new BSS, the concept of action levels is abandoned and 'reference levels' established, which are defined as levels of dose or risk above which it is judged to be inappropriate to plan to allow exposures to occur, and below which optimization of protection should be implemented. By maintaining the same numerical values of dose (for instance, a maximum of 10 mSv per year in the case of indoor radon exposure) resulted in a significant increase in the stringency of protection measures in existing exposure situations, removing a lower bound on the application of the optimization process. In the new BSS and the draft safety guide, the action levels have been replaced by maximum reference level of 1000 Bq/m^3 for workplaces, which corresponds to a dose of the order of 10 mSv per year.

c) Itinerant workers

Workers who regularly carry out their work on the premises or site of another employer and may be exposed to the site operator's use of radiation or may take onto the site their own source of radiation, with exposure implications for both themselves and the employees of the site operator. These persons are referred to as itinerant workers and are often employed by contractors. Guidance on issues associated with the use of itinerant workers, cooperation between different employers, sources under the control of a facility, sources under the control of a contractor, competence of itinerant workers, radiation protection programme, monitoring and recording of occupational exposure, training, review of protection and safety, issues associated with specific types of facilities etc. are provided.

d) Female workers during and after pregnancy

Additional protection measures have to be considered for a female worker during and after pregnancy in order to protect the embryo, foetus, new-born or breast-fed child. As soon as a female worker notifies the employer that she is pregnant or is nursing the new-born or breast-fed child, the employer should make special arrangements with respect to her working conditions to ensure that the embryo, foetus or child is afforded the same broad level of protection as is required for members of the public. Detailed guidance on exposure pathways, responsibilities of management, monitoring and dose assessment in these special cases have been addressed in Section 6 of the guide.

e) Emergency exposure situations

Guidance on the updated requirements set out in the new BSS and GSR Part 7 [4] has been revised. Following a similar approach to that for existing exposure situations, the new text includes requirements on the use of reference levels. Guidance is provided on the different groups and categories of workers who would be involved in a nuclear or radiological emergency. The table of dose guidance values to restrict exposure to emergency workers have been further updated in line with the requirements set out in the GSR Part 7.

f) Exposure of workers to natural sources

In terms of paragraph 3.4 of the BSS, occupational exposure to natural sources is in general subject to the requirements for existing exposure situations. This is always the case when the exposure is due to radionuclides of natural origin in everyday commodities (food, feed, drinking water, agricultural fertilizer and soil amendments, and construction material) and in existing residues in the environment, regardless of the radionuclide activity concentrations. In the case of occupational exposure to radionuclides of natural origin in materials other than these everyday commodities and in residues in the environment (these 'other' materials being essentially industrial process materials) the applicable requirements depend on the radionuclide activity concentrations. If, in any process material, the activity concentration of any radionuclide in the ^{238}U or ^{232}Th decay chain exceeds 1 Bq/g, or if the activity concentration of ^{40}K exceeds 10 Bq/g, that material is regarded as NORM, the industrial activity is regarded as a practice and the requirements for planned exposure situations apply; and if the concentration is 1 Bq/g or less then the requirements for existing exposure situations apply. Detailed guidance on industrial activities that are, or may be, subject to the requirements for planned exposure situations are explained in section 5 of the guide. The application of the graded approach, prior radiological evaluation and control of worker exposure are elicited in the guide.

g) Existing exposure situations: remediation of contaminated areas

Workers exposed while carrying out remedial action and workers exposed as part of the existing exposure situation, but do not undertake any remedial action are considered to be occupationally exposed. The doses received in existing exposure situations are expected to be well below the threshold for deterministic health effects. Therefore, stochastic health effects are the only health effects of concern. Detailed guidance on protection strategies, justification, optimization and organizational arrangements are given.

h) Existing exposure situations: occupational exposure to cosmic rays

Occupational exposure to cosmic rays is covered in the Safety Guide. BSS requirements for exposure of aircrew and space crew have been elaborated and a reference level of 5 mSv/a was recommended for aircrew exposure. Essentially, the relevant regulatory body is required to determine the need for, and extent of, specific protection measures according to the particular circumstances. Guidance on sources of exposure, application of the system of protection and safety, exposure of air crew and exposure of space crew are provided.

i) Assessment of occupational exposure

The section 7 of the draft guide provides detailed guidance on external and internal dosimetry. This section basically targets the guidance provided in the safety guides RSG 1.2 and RSG 1.3 together and updates according to the latest knowledge and recommendations of the ICRP. Guidance is also provided on assessing the dose to the lens of the eye.

CONCLUSIONS

The new safety guide on occupational radiation protection is comprehensive in nature and covers all situations of exposure to workers. It provides detailed guidance on fulfilling the requirements of the new International basic safety standards for occupational exposure. The structure of the current safety guide is complex as it is inevitable due to bringing out all guides relevant to occupational exposure in a single comprehensive guide. In a closer look, it can be seen that the guide is useful for practical implementation and covers all types of exposure situations. For existing exposure situations, the new 'reference level' approach has been adopted, and this will have the intended effect of increasing the level of protection against exposure to natural sources by removing any lower bound on the optimization process. The new guidance provided for the itinerant workers, female workers during and after pregnancy, exposure to NORM, exposure to radon, exposure to cosmic rays etc. would greatly facilitate in implementing the protection and safety requirements as well as harmonizing the radiation protection of workers worldwide.

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ICRP SYSTEM OF PROTECTION — PRESENT AND FUTURE

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Abstract

The International Commission on Radiological Protection (ICRP) system of protection provides a basis for occupational protection in any exposure situation. Originally developed to provide protection in the early days of use of radiation and radioactive materials, the system has, and continues, to evolve to address the risks of radiation exposure, and to provide a coherent, systematic approach to controlling exposure. The current work of the ICRP examines the extension of the system of protection to emergency and existing exposure situations, which were not treated in a completely satisfactorily manner prior to the most recent recommendations of the ICRP in Publication 103.

INTRODUCTION

The International Commission on Radiological Protection (ICRP) was formed in 1928 as the International X-ray and Radium Protection Committee. From its inception, the ICRP has been addressing the risks of radiological protection, and in particular protection for those individuals who use radiation and radiation sources in various medical and industrial settings.

The mission of the ICRP is to advance for the public benefit the science of radiological protection, in particular by providing recommendations and guidance on all aspects of protection against ionizing radiation. The aim of the ICRP's recommendations is to contribute to an appropriate level of protection for people and the environment against the detrimental effects of radiation exposure without unduly limiting the desirable human actions that may be associated with such exposure. In doing so, the objective is to prevent deterministic effects of exposure, and to reduce the possible stochastic effects (genetic, cancer, non-cancer) to levels that are As Low As Reasonably Achievable, economic and social factors being taken into account.

Over time, the recommendations were first focused upon the prevention of deterministic effects, as evidenced in early researchers in the field. As knowledge of radiation effects has expanded, the recommendations have been updated and modified to address the information available. The most recent recommendations were published in 2007 as ICRP Publication 103.

SYSTEM OF PROTECTION

The system of protection can now be envisioned as a set of interrelated components comprising principles of protection, exposure situations, categories of exposures, dose criteria, and key requisites for implementation. The system can be illustrated as shown in Figure 1.

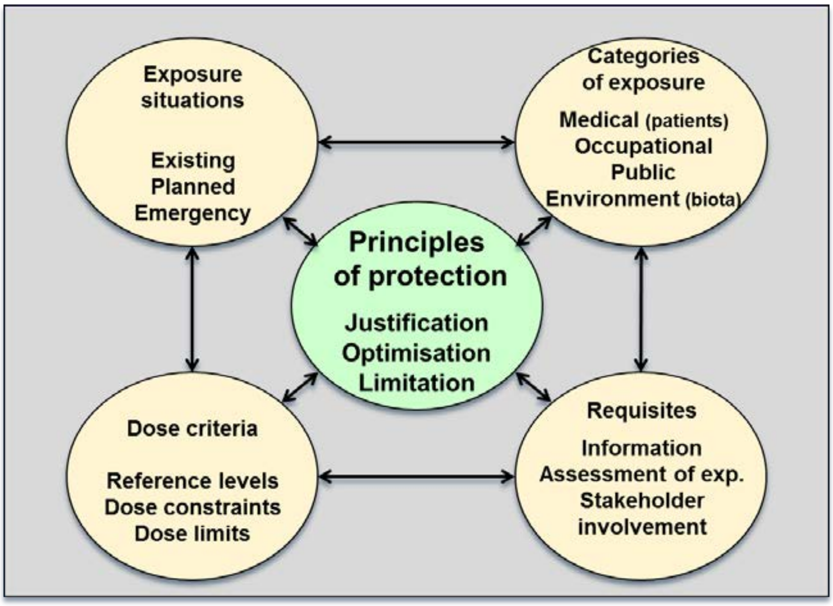

FIG. 1. ICRP System of protection.

The principles of protection, namely justification, optimization, and limitation, provide a coherent and systematic approach to addressing exposure in any exposure situation. While the system of protection grew and originally was developed in the context of what is today termed planned exposure situations, existing exposure situations and emergency exposure situations are now to be approached in a similar manner. Specifically, it must first be determined that the implementation of a protective action, is justified, and then protection should be optimized.

Dose criteria for restricting the exposure of an individual in the particular circumstances provide a method to ensure that the optimization process is equitable. The dose criteria recommended by the ICRP include dose constraints in planned exposure situations, and reference levels in existing and emergency exposure situations. Dose limits are a specific form of dose criteria, applied in planned exposure situations. In this context, the dose limit is a individual related criteria, intended to provide a benchmark for the acceptable level of exposure from all sources to a particular individual. In the case of occupational exposure, this is usually well defined. The ICRP is aware that many authorities choose to use the same term, limit, to represent the legal construct of a dose that is not to be exceeded as a result of the activities under a licensee's control. This is an equally valid use of the term, but has caused confusion in understanding and implementing the system of protection.

The categories of exposure, specifically occupational, public, and environment may be present in any of the exposure situations. Medical exposures are a category that only occurs in planned exposure situations. What is important to note here is that occupational exposure can occur in any of the exposure situations, and needs to be treated appropriately in each circumstance. In the early phases of an emergency exposure situation, responders, whether or not normally occupationally exposed, may not be under the usually expected conditions of occupational exposure, due to the circumstances.

Implementation of a system of protection also has several fundamental requisites in order to ensure that the system operates effectively. Information, both in terms of training, and in terms of provisions of important information to various groups, is critical for each individual to ensure safety. Assessment of exposures are necessary on an ongoing basis, particularly in occupational exposure, to understand the conditions, assess the relevance of safety measures, and provide feedback on possibilities for improvements consistent with optimization. Finally, Stakeholder involvement is key to ensuring that protection information is widely available, and to involve all of the interested parties in the discussions. In the case of occupational exposure, stakeholders include the individual workers, and stakeholder involvement is a component of the broader consideration of safety culture, or safety conscious work environment, where each individual contributes to safety.

The system of protection is built upon a broad set of foundations, encompassing social and ethical values, science, and experience. The contributions of these components is illustrated in Figure 2.

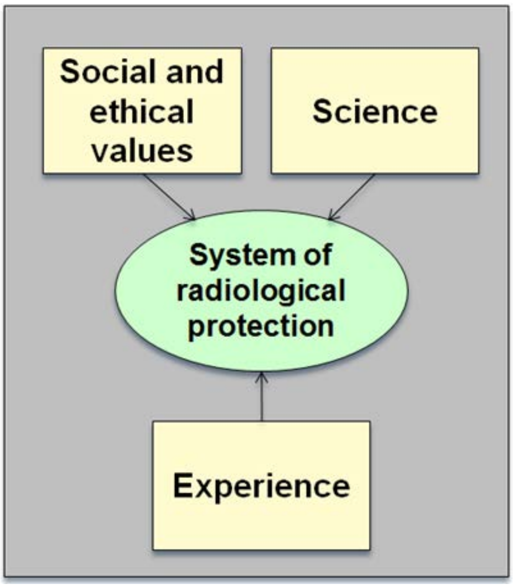

FIG. 2. Foundations of the system of protection.

The social and ethical values include:

- Beneficence, that is to do more good than harm;
- Prudence, to keep exposure ALARA and avoid unnecessary risk in the face of uncertainties;
- Justice, to reduce inequities in dose and ensure that no individual carries an unacceptable share of the risk or harm, now or in the future;
- Dignity, to involve stakeholders and treat people with respect.

Two additional values, namely reasonableness and tolerability, are key values in the practical implementation of the system of protection. Tolerability is a factor of the circumstances the individual finds themselves in, and the amount of time over which those circumstances may continue. When all is “peaceful” or routine, then generally a person does not pay a great deal of attention to the question of risk or safety. The expectation is that circumstances are very well controlled and the risk if very low. When there is uncertainty in the circumstances, the individual becomes vigilant, and looks to see if there are actions that can be taken to possibly reduce risks. Finally, when circumstances are out of control, the individual is in a reaction mode, taking immediate actions to try and reduce risks. In fact, occupational exposure should always be associated with some degree of vigilance. There are many cases where routine leads to complacency, which can then lead to accidents.

Scientific foundations are found in many disciplines, including the information gained on radiation effects from epidemiology, cellular biology, radiobiology, etc. Our understanding of the effects of radiation continues to grow and evolve, and our understanding of fundamental biological systems has enabled continued advances in the modelling and prediction of the movement of radionuclides into, and through the body, and in the environment.

Experience also plays a key foundational role in our system of protection. The system is, at least to some extent, a product of our learning from and responding to significant events and operational experience. A particular case in point at this time is applying the lessons from the events at Chernobyl and more recently at Fukushima Daiichi to the system of protection, and developing information to help resolve perceived gaps and issues identified. Experience has shown that the system of protection is fundamentally sound, and effective.

Turning to occupational exposure, it is important to recall first that an exposure situation is any process causing human exposures, either from natural or man-made sources. Protection can be achieved by taking action at the source, or at points in the exposure pathways, and occasionally by modifying the location or characteristics of the exposed individuals. This is illustrated in Figure 3. All of these possibilities are present for occupational exposure.

FIG. 3. Components of an exposure situation.

Once an exposure situation is identified, then the process of exposure assessment and considerations of optimization of protection can begin. As illustrated in Figure 4, an exposure assessment may show many types of exposure distributions, depending on the situation. The process of optimization is to assess what actions can be properly taken to shift exposure towards lower values of dose, and influence the entire dose distribution. In some cases significant reductions in the dose, and the distribution can be made, while in other cases, such as exposure of air crew to cosmic radiation while in flight, a significant change in the shape of the distribution may not be possible. Individual dose criteria operate in conjunction with the optimization process to reduce inequity, and to identify exposure which warrant specific attention to reduce their magnitude. In Figure 4, the line indicating individual dose criteria is placed within the optimization arrow to signify that individual exposures may be greater than what might be planned for when an exposure is identified, such as in existing and emergency exposure situations. Optimization is to act on the exposure distribution to influence the magnitude and distribution to achieve doses within the established dose criteria, and to continue to reduce exposures consistent As Low As Reasonably Achievable. Unlike the old paradigm of intervention, it is not sufficient to simply achieve some particular level, which was called an intervention level. Optimization continues to be operative, irrespective of the exposure situation.

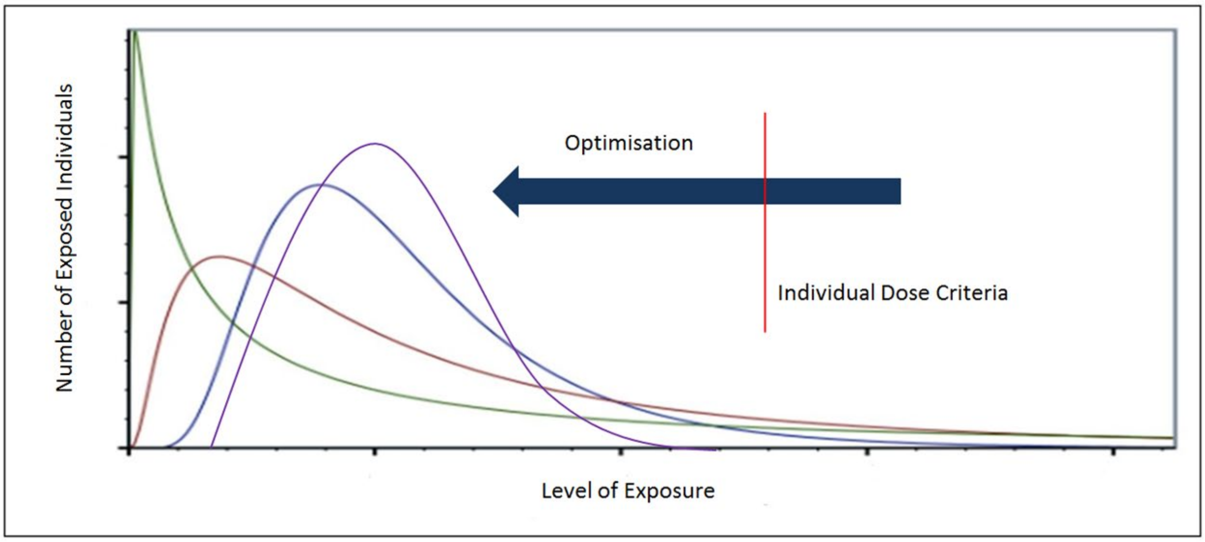

FIG. 4. Dose distributions, optimization and individual dose criteria.

Let us now turn to the three specific cases of occupational exposure to illustrate the current directions and approach. Radon exposure has received a great deal of attention over the last couple of years, with information on changes in our understanding of the relationship between exposure and risk. ICRP currently has in press Publication 126, which will describe a systematic graded approach based on optimization that can be applied across the spectrum of situations. Although there is considerable information on the impact of smoking on the risks from radon, the ICRP has not suggested that distinction be made between smokers and non-smokers, particularly in wide-spread populations. Publication 126 will recommend an approach which can be applied to all buildings, whatever the use, whether residential, or with various types of work. The graded approach in workplaces recommended first looks to determine if the derived reference level in activity concentration can be achieved in the building. If so, further efforts to consider and account for the radon exposure are not likely to be warranted. The value selected is the same as for dwellings, because at this first level no distinction should be necessary between any person of the public, and someone who happens to be working in the building, such as a bank employee. When such nominal measures are insufficient to reduce the activity concentration, a more detailed assessment based on the dose to individuals in the building may be undertaken, including in various occupational settings, using a dose-based reference level of 10 mSv/y. Actions to reduce the contributions to within the reference level would likely result in there being no need to apply the full scope of controls normally associated with occupational exposure. Doses in excess of approximately 10 mSv would likely indicate that radon would need to be more completely included in the occupational dose assessment and control program, applying the requisites of assessment, information, stakeholder involvement. The ICRP continues to recommend that occupational dose be within a value of 20 mSv for all radiological contributions of exposure.

Another area of work by ICRP's Committee 4 is an examination of the various issues in use of naturally occurring radioactive materials, or NORM. There are a wide range of industrial practices that may involve naturally occurring materials, many of which are not intended to specifically use the radioactive properties of the material. A priori, whether the activity is specifically to use the radioactive properties, or some other purpose such as mineral extraction, is not a fundamental decision point in determining if radiological controls are needed. Many of these industries have been in place for many, many years, and there may be a lack of awareness that radiological protection may be an issue. In general terms, the approach recommended to characterize the situation, and determine the types and magnitudes of occupational exposures that may be present. Many cases may not warrant the imposition of a formal system of occupational controls, but generic prediction is difficult. If controls are determined to be warranted, the protection should be optimized.

A third example of occupational exposure issues comes from the experience from the events at Chernobyl and Fukushima Daiichi. The example given here is the question of how to deal with the exposures of individuals who may be responding to an event. In fact, defining who the responders may be is a considerable challenge. When the event is at a licensed facility, then licensee employees and contractors will be present, and rather obviously would be considered as occupationally exposed. It is more difficult to determine the specific categorization of other individuals, such as offsite professionals such as fire and rescue personnel who may respond, other workers who may be providing transportation services, or providing critical needs to a response such as electrical contractors, and even, in some cases, members of the public. The last group might be more likely to be present in a situation where an event takes place in a public venue, such as any postulated radiological terrorism. We witness nearly everyday events in the news where someone runs into an accident scene to save someone. What if there had been radioactive material? The factors that become important in considering the levels of protection to be applied include the circumstance of the exposure, including the time frame and the status of the individuals when some consideration can be given to use of controls, the training and knowledge of the individuals, the location of various individuals, etc.

Consistent with an optimization approach, individuals should be examined, and individual dose criteria should be applied. The bands of exposure provide a basis for assigning these dose criteria, but should not be seen as mandating that the dose criteria must be within the band. It may well be that dose criteria can be selected lower than the band for particular groups of individuals, and thus the bands should be seen as providing an upper boundary on the selection. I will return to this point in a moment.

Another issue is how to apply the dose criteria and radiological protection transition from an emergency to an existing exposure situation. Figure 5 illustrates some of the key points in the transition. In an emergency exposure situation, the reference level for occupation exposure might be in, or below (if possible) the 20–100 mSv per year range. Protective actions are driven by urgency, and must be undertaken rapidly to deal with the situation. Requisites of training, dosimetry, tracking of individuals should be in place to the greatest extent possible. As additional information becomes available, the situation is no longer evolving, and additional planning and thought can be given to protection. Gradually this should mean that the reference level selected for occupational exposed can return to within or below the 1–20 mSv band, and more deliberate actions can be taken to reduce and maintain exposures ALARA driven by information and controls. Also important is the opportunities for stakeholder involvement in the decision process.

CONCLUSIONS

In conclusion, ICRP Committee 4 is moving towards a more unified approach to examining protection irrespective of the exposure situation. This approach includes the recognition that occupational exposure can occur in any exposure situation, even if the degree of controls may be different at different times. The characterization of the exposures is a prerequisite for any actions, whether a priori in planned situations, or in an evolving awareness with existing and emergency exposures.

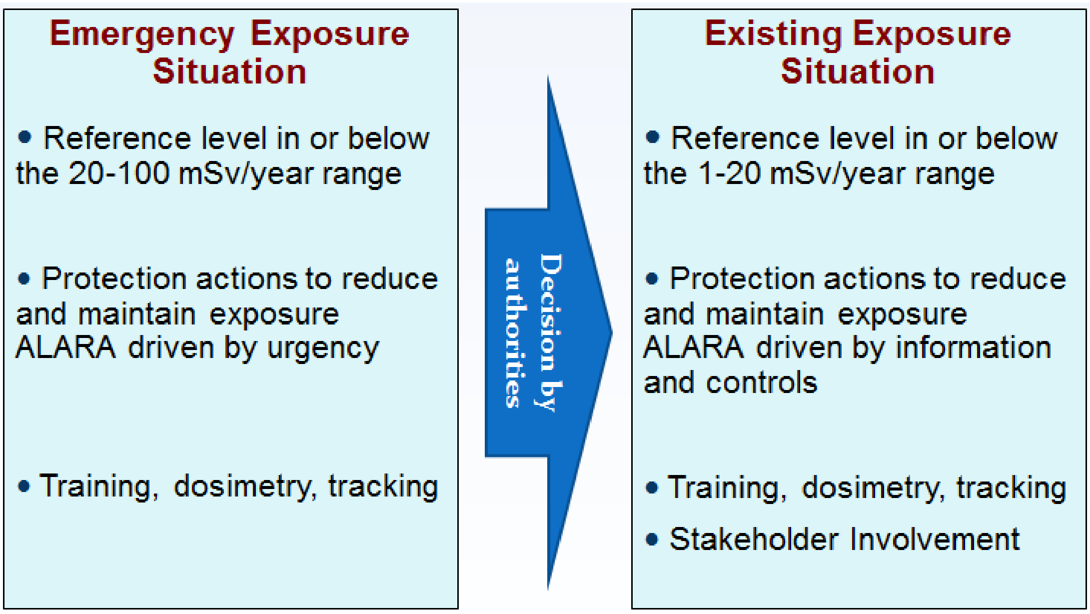

FIG. 5. Transition from emergency to existing exposure situation.

Once the exposure situation has been characterized, then justification of establishing controls is necessary, taking into account the opportunities for exerting control upon the source, the pathways, or the individuals, and taking into account other social and economic factors. If controls are determined to be justified, then exposures are managed using optimization of protection using restrictions on individual doses to reduce inequity, identify exposures which warrant specific attention to reduce their magnitude, and to guide reduction in the entire dose distribution by keeping exposures As Low As Reasonably Achievable. The selection of individual criteria to apply to the optimization should be within, or below, the bands recommended in Publication 103, namely within or below the 1–20 mSv/y band for existing and planned exposure situations, as appropriate, and within or below the 20–100 mSv/y band for emergencies, if necessary. It is critically important to select values that are actually useful in the optimization of protection. The dose criteria should be selected at the level that allows for effective identification of exposures that warrant additional attention, and which assist in improving protection through optimization.

The basic requisites of information and assessment of exposures, and the involvement of stakeholders, are to be applied commensurate with risks. Finally, it is recognized that authorities may choose to manage certain types of exposures with the tools, such as a dose limit, normally associated with planned exposure situation. This application, where an individual criterion is given a specific legal context, can be appropriate using a graded approach to provide a systematic, transparent, and equitable management of exposures. It is important to be clear when a dose criteria is given a specific legal context, and the legal implications of the selection of such a criterion in a particular situation

RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS – TOPICAL SESSION 1

T. Zodiates

ITUC, EDF, United Kingdom

INTRODUCTION

This report briefly summarizes the contributed papers for topical session 1 of Day 1 (1 December 2014) of the Second International Conference on Occupational Radiation Protection, IAEA, Vienna. There were 14 papers submitted for this session. The distribution of the origin of the papers is as follows:

- Asia – 5
- Latin America – 2
- Africa – 4
- Europe – 2
- North America – 1

The papers dealt with planned exposure situations covering the Medical Applications, Industrial Applications, Education & Research and Nuclear Power & Fuel Cycle operations.

Many of the papers reviewed the evolution of occupational radiation exposures of the country. Whilst occupational exposures, both individual and collective, in nuclear power plants have reduced over time, the experience in other areas is mixed. Collective doses in industrial and medical applications depend on the extent of usage and changes in individual doses have not been significant.

Many of the submitted papers identify similar issues and challenges in the application of occupational radiation protection. In the rapporteur's view, based on the information in the papers, the implementation of the revised standards is only a small part of these issues and challenges. The most important are:

Lack of Finance and Resources,
Lack of Occupational Radiation Protection Infrastructure, and
Insufficient number of dosemeters.
And at the next level:
Lack of competent staff, in particular Radiation Safety Officers;
Lack of internal dose assessment;
Lack of extremity assessment;
Regulator as a Technical Support Organization (e.g. dosimetry service);
Nuclear Plants: itinerant workers;
Mines: ventilation issues / uncertainties in internal dose assessment; and
Medical: RP awareness is low.

Two papers dealt with the practical application of the standards:
ALARA: one paper presented an interesting approach for the derivation of alpha values, i.e. monetary value of dose, for use in Cost Benefit Assessments; an example of the implementation of an Occupational Radiation Protection Structure was described in another paper.

In summary, although there is a delay between the update of international standards and their incorporation into legislation, in many less affluent countries the major issues and challenges relate to the practical implementation of the radiation protection requirements.

CHAIRS' SUMMARY OF TOPICAL SESSION 1

INTRODUCTION

The keynote lecture was given by M. Pinak, IAEA, on the International Basic Safety Standards. S. Mundigl, European Commission, presented the Euratom Basic Safety Standards Directive. P.P. Haridasan, IAEA, addressed the international guidance on occupational radiation protection. D.A Cool, ICRP, reviewed the ICRP protection system, particularly regarding occupational radiation protection. T. Zodiates, ITUC, summarized the contributed papers of the session.

M. Pinak, IAEA: The International Basic Safety Standards on radiation protection and the safety of radiation sources were published in July 2014. Stability dominates: Justification, Optimization and Dose Limitation continue to be the fundamental principles and recommended dose limits, except for the lens of the eye, remain unchanged. Optimization and the application of dose constraints remain very important in planned exposure situations. Using reference levels, optimization is extended to apply also in existing and emergency exposure situations. Requirements for occupational exposure cover the responsibilities of the regulatory body and the principal parties; worker compliance; information, instructions and training; classification of work areas; monitoring and recording of exposures; assessment of exposures; local rules and personal protective equipment; and special arrangements (pregnant and breast-feeding women, students and apprentices).

A challenge is to create the RP system and establish work cultures so that the prime responsibility for protection and safety remains with the authorized parties and to implement optimization so that "ALARA" is achieved and while legal requirements are still met. The government and the regulatory body should ensure that protection and safety is optimized but the establishment of constraints and the actual optimization should usually be left to, involving the workers, the authorized/principal parties. A timely challenge is managing exposures in emergency situations. To avert large collective doses, save lives or prevent severe deterministic effects, individual doses between 100 - 500 mSv are acceptable. The matter will most certainly merit from further discussions and more guidance.

S. Mundigl, EC: The EURATOM Treaty empowers the European Community to establish legally binding basic safety standards for the protection of the health of workers and the general public – the Euratom Basic Safety Standards Directive (EBSS). Already the first EBSS from 1959 contained detailed requirements on occupational RP. Since then, EBSS was regularly amended reflecting progress in scientific knowledge, technological development and operational experience. This has resulted in a high level of the RP for workers in Europe.

In December 2013, the Council of the European Union adopted the latest revision of EBSS which modernizes and consolidates the European RP legislation. It constitutes RP safety standards covering all relevant radiation sources, including natural ones, integrates the protection of workers, members of the public, patients and the environment, covers all exposure situations, and harmonizes numerical values with international standards. EBSS offers better worker protection, including emergency workers and workers exposed to enhanced levels of natural radiation sources, such as air crew or workplaces with high radon concentrations. The incorporation of the former Outside Workers Directive into EBSS provides for clear allocation of responsibilities for the protection of a transient worker between the employer and the operator of the controlled area where work is performed. Last but not least, EBSS offers better protection for medical staff, including the lowered dose limit for the lens of the eye. The EU Member States have four years for the transposition and implementation of this new Directive.

P.P. Haridasan, IAEA: A new IAEA safety guide on ORP is being developed. The guide, prepared jointly by IAEA and ILO, covers all exposure situations and all facilities and activities involving ionizing radiation. It advises on the establishment of radiation protection programmes and on monitoring and assessment of doses from external radiation as well as intakes of radioactive material. It includes guidance on the protection of female workers during and after pregnancy, itinerant workers, exposure to natural radiation sources (radon, NORM, cosmic rays), protection of emergency workers, monitoring of the dose to the lens of the eye etc. This comprehensive safety guide will update and supersede five existing guides on occupational radiation protection, assessment of exposures, and the management system for technical services in radiation safety. The draft has been submitted to the Commission on Safety Standards for approval.

D.A. Cool: The ICRP system of protection is structured to provide a consistent approach to protection against ionizing radiation in all exposure situations (existing, planned, and emergency) through justification of protection actions, and optimization of protection using individual dose criteria to identify individuals that warrant specific attention and modify the distribution of exposures to levels that are as low as reasonably achievable. Dose limits are a specific form of individual dose criteria that may be used by a competent authority to identify values that are legally unacceptable in a specific set of circumstances. Occupational protection can be systematically approached through assessment of exposures, optimization of protection, and involvement of the stakeholders, particularly the individual workers themselves in a strong radiation protection culture.

T. Zodiates, ITUC: The submitted papers dealt with planned exposure situations covering: Medical Applications, Industrial Applications, Education & Research, and Nuclear Power & Fuel Cycle. Many of the papers reviewed the evolution of occupational radiation exposures of a particular country. Whilst occupational exposures in nuclear power plants have reduced over time, the experience in other areas is mixed. Many papers identified issues and challenges in the practical application of occupational radiation protection. The most important being a lack of finance and resources, lack of ORP infrastructure, insufficient number of dosimeters. In more detail challenges are associated with:

- Lack of competent staff, in particular Radiation Safety Officers;
- Lack of internal dose assessment;
- Lack of extremity assessment;
- Regulator as a Technical Support Organization (e.g. dosimetry service);
- Nuclear Plants: itinerant workers;
- Mines: ventilation issues / uncertainties in internal dose assessment; and
- Medical: RP awareness is low.

CONCLUSIONS

The international radiation protection system and standards remain stable and effective. The fundamental principles of Justification, Optimization, and Limitation are acknowledged. Changes to ensure better worker protection and a unified approach include:

- Harmonized measures developed for planned, existing, and emergency exposure situations.
- A broader occupational radiation protection scope which covers natural radiation sources (cosmic rays, NORM, radon), outside workers and RP in emergency situations.
- A proactive approach to the use of radiation screening systems (e.g. whole-body scans) so that worker's safety is not obscured.
- Introduced amendments should be based on science and experience feedback, e.g. the new dose limits for the lens of the eye, development of radiation protection in emergency situations.

Optimization is a key issue in radiation protection and is now used in all exposure situations. It should be a structured process to reach the desired objective. Dose constraints or reference levels are tools to ensure equity. A graded approach should be implemented in all exposure situations.

It remains vital to foster a good radiation protection culture. The effective implementation of a protection system requires awareness, dialogue and the engagement of stakeholders.

At present, the focus should be on the practical implementation of the standards and assistance to countries with less developed RP programs is important.

TOPICAL SESSION 2:

DOSE ASSESSMENT OF OCCUPATIONAL RADIATION EXPOSURES

Chairpersons: J. Hunt, Brazil and F. Wissmann, Germany

RADIATION MONITORING AND DOSE ASSESSMENT — KEY REQUIREMENTS FOR THE IMPLEMENTATION OF THE PRINCIPLES OF LIMITATION AND OPTIMIZATION IN OCCUPATIONAL EXPOSURE

H.G. Menzel

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Abstract

The implementation of the principles of limitation and justification of radiation protection recommended by the International Commission on Radiological Protection (ICRP) require the use of appropriate quantities. Effective dose and equivalent dose to organs and tissues are protection quantities introduced by ICRP for this purpose and are used in national legislation and regulations to set dose limits, constraints and reference levels. The practical implementation to demonstrate compliance with regulation in the various activities of occupational exposure requires the use of instruments and their standardization and technical guidance. The paper describes the complimentary role of ICRP, ICRU, Basic safety Standards and international standards organizations in practical implementation of radiation monitoring and dose assessment in occupational exposure.

More information can be found at the link: https://iopscience.iop.org/article/10.1088/0952-4746/32/1/N41/meta

Dosimetric quantities in radiological protection and risk assessment. Hans-Georg Menzel and John Harrison, Published 6 March 2012, IOP Publishing Ltd. Journal of Radiological Protection, Volume 32, Number 1

THE STATUS AND CHALLENGES OF EXTERNAL DOSIMETRY

F. Vanhavere

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Abstract

In this paper we will discuss the status and challenges of external personal dosimetry. Based on the results of the EURADOS intercomparisons it can be shown that the international requirements for accuracy of personal dosemeters (trumpet curve) are quite well achieved by the present generation of dosimetry services. Still, improvements are needed, for example for neutron dosemeters, for low energy beta dosimetry and for extremity dosemeters. Further 101anada101g101d101n in the ergonomy of the dosemeters, especially for ring and eye lens dosemeters, will also lead to better dosimetry. The increased use of active dosemeters enhances the feedback to the workers, and thus improves the radiation protection in the framework of ALARA. Recent developments where the results from passive devices can be consulted at any time by the worker, and where no dosemeters need to be returned for read out will also lead to an improved personal dosimetry.

INTRODUCTION

The dosimetric quantities recommended for radiological protection purposes, and in which the dose limits are expressed, are the effective dose E and the equivalent dose HT in a tissue or organ T. These are called the protection quantities. The dose limits are such that deterministic effects will not occur for the organs and tissues included in the definition of effective dose. Occupational exposed workers need to be monitored with dosemeters from an approved dosimetry service to check if these limits are not surpassed.

As the effective dose is a non-measurable quantity, operational quantities are defined. These operational quantities provide a good conservative estimate of the protection quantities. The operational quantity for individual monitoring is the personal dose equivalent Hp(d), where d is 10 mm, 3 mm or 0.07 mm, for the assessment of effective dose and equivalent dose to the eye lens and local skin, respectively.

So, the basic objective of a personal dosemeter is to provide a reliable measurement of the operational quantities Hp(0.07), Hp(3) and Hp(10) for all practical situations, independent of the type, energy and direction of the radiation, and with a prescribed overall accuracy. Other dosemeter characteristics which are important from a practical point of view include the size, the shape, the weight and the identification system.

MATERIALS AND METHODS

At present, different types of passive personal dosimetry systems are used in the world. While in the past mainly film dosemeters and TLD (thermoluminescent dosemeters) were used, at present RPL (radiophotoluminescent), DIS (direct ion storage) and especially OSL (optically stimulated luminescent) dosemeters are getting more and more popular. The film dosemeters are clearly on the decline. For TLD the most popular materials are still LiF:Mg,Ti, LiF:Mg,Cu,P and $LiBO_4$. For OSL, next to the widely used Al_2O_3:C, a system with BeO is now available.

A trend is also to go to bigger dosimetry services. In many countries dosimetry services now need approval from their authorities. This puts some more strict requirements on the services, like ISO17025 accreditation. This is an extra effort that can be difficult to obtain for small services. These extra requirements can also imply that it is no longer economically viable to run a small dosimetry service. As such, in many countries, the number of dosimetry services is decreasing, and bigger companies take over customers and services or start to work together with smaller services. This scale enlargement is not necessarily a negative evolution. In some smaller services there is a lack of knowledge and manpower to follow all the newest developments and improvements. In general, such national regulatory requirement for approval of dosimetry services increases the overall quality of dosimetry.

Guidelines concerning the accuracy that is needed for measurements with individual dosemeters is given in ICRP Publication No. 75 [1]:

(a) In the region near the relevant dose limit, a factor of 1.5 in either direction is considered acceptable;
(b) In the region of the recording level, an acceptable uncertainty of ±100% is implied.

This leads to the well-known trumpet curve. This trumpet curve can be used in intercomparisons to judge on the performance of a dosimetry service.

Such a performance criterium for a personal dosimetry service may seem not very strict. When measuring low doses (few hundreds of μSv in one month) an uncertainty of a factor 2 is accepted. This is certainly a lot compared to e.g. gamma spectrometry, where often the number of Bq in a sample can be given within a few percent. The reason why the ICRP has this requirement is because when estimating the risk for any stochastic effect on a worker, even larger uncertainties are involved in the further steps.

A first aspect is that a dosemeter is not measuring effective dose, but dose equivalent, Hp(10). This Hp(10) is not always a perfect estimation of the effective dose. There is an important uncertainty associated with this, especially in case of non-homogeneous exposures. Hp(10) is certainly not an ideal operational quantity. For example, in the same irradiation field the Hp(10) for a corpulent person will be higher than that for a thin person (because of the backscatter). Still, the effective dose from the corpulent person will be lower. More in general, it is clear that the present system of operational and protection quantities is not reflecting any personal variation in sensitivity for radiation.

Secondly, to translate the number of sieverts effective dose into a risk, epidemiological data are used, like the data from Hiroshima and Nagasaki follow up. It is clear that there are very large uncertainties on these data, orders of magnitude bigger than the uncertainty on the dosemeter results. Thus, reducing the uncertainty on the dosemeter results, will not have much influence on the total risk estimation.

However, all this does not mean that the dosemeter should not try to give an as accurate as possible estimation of Hp(10). A smaller uncertainty on the dosemeter will always give a better estimation of the risk, and it will also make that the worker will trust better the dosemeter, and thus will result in a better discipline in using it.

In principle the dosimetry services should report also the uncertainty on their measurements, especially when the services follow ISO17025. Not many services do this at present, because reporting such a high uncertainty (up to a factor 2) might lead workers (and their employers) to distrust the results. Although it will not enhance significantly the accuracy of the risk estimates, reducing the overall uncertainty on the dosemeter results will certainly help in the general acceptance of the dosemeter results by the workers.

Errors in estimating Hp(10) can come from the non-perfect design of the dosemeter or from errors in calibration and processing by the dosimetry service. For the dosemeter (including the reader device) requirements are laid down in the IEC 62387 standard [2]. Basically, the main sources of uncertainty in the measurement of Hp(10) come from the energy and angular dependence of the dosemeter. Besides this, contributions from fading, background subtraction, non-linearity, environmental influences, other types of radiation, may play a role.

In a workplace situation it is not known with which energy and angle, and at what time the dosemeter was irradiated. For an ideal Hp(10) dosemeter this would not matter. Unfortunately, even the best passive devices show some energy and angular dependence. This can typically be 10-20% (1s). When low energies and large angles are used, this can be even much higher. So efforts should be made to make dosemeters more independent on the angle and energy of the radiation.

A good image of the performance of present dosimetry services can be obtained from the results of the EURADOS intercomparisons. Since 2008, EURADOS is 103 anada 103 g 103 d intercomparisons for the dosimetric community. The EURADOS intercomparisons are mostly aimed at European services, but more and more countries from outside Europe are joining. The number of services participating is increasing every year. A thorough statistical analysis was made from all results since the 2012 intercomparisons [3]. In total 87 systems participated, where 68% used TLD, 14% used film dosemeters, 13% used OSL dosemeters and 6% used other systems (DIS, APD, RPL). Different radiation qualities were given, like S-Co, S-Cs and N-60 under 0° and 60°. From the almost 1400 irradiated dosemeters, only 6% of the data points were outside the trumpet curve limits. In total 79% of the systems showed no outliers at all, and 90% fulfil the criterium of ISO14146 (maximum 2 outliers). The overall mean response was 0.98 compared to the reference. Improvements can of course be made (there was an almost systematic overresponse for N-60 at 60°), but these results show that dosimetry services have no problem in satisfying the present performance criteria of the trumpet curve. We could conclude here that no improvement is needed anymore for personal dosemeters, because almost all services can measure the reference doses quite well.

Of course, it should always be remembered that during intercomparisons relatively standard fields are given, without any difficult environmental condition or other possible influence factors. Up to now, no high energy gamma's (>S-Co) nor large angles (>60°) were included in the EURADOS intercomparisons. The results would probably also be worse if real workplace fields were to be used. But still these results show the good performance of the (mainly European) dosimetry services compared to the trumpet curve criterium.

For the extremity dosemeters, the situation is different. During the 2009 EURADOS intercomparison 59 systems participated (from 44 services) [4]. The number of outliers for the gamma irradiations was 10%, while for the beta irradiations it was 35%. The lower the energy and the larger the angle, the worse the results. For a Kr-85 irradiation, 65% of the results were outside the trumpet curve. This clearly indicates that a lot of improvement is still needed for extremity dosemeters.

For neutron personal dosemeters the situation is much worse than for gamma beta dosemeters. The ICRP states that from considerations of the response characteristics of neutron personal dosemeters, there are certainly difficulties meeting the criteria for neutrons. Even with a criterion of a factor of 2, it might not be possible with any current design of dosemeter to meet the criterion over the full range of neutron energies possibly present in the workplace. For neutrons, an intercomparison was 104anada104g104 by EURADOS in 2014[5]. In total 34 systems participated. The intercomparison was 104anada104g104 in two steps, because many systems require information of the radiation field before being able to give reliable results. This alone is already an indication that improvement is really needed in neutron personal dosimetry. As a final result, roughly half of the systems were able to estimate the reference doses within a factor 2. Again, here the results are much worse than for gamma whole body dosemeters, which means that neutron personal dosimetry is not a solved issue.

Of course, it is clear that the radiological characteristics are not the only important aspects of personal dosimetry. A significant part of the uncertainty in estimating the dose from a worker comes from not wearing a dosemeter systematically, or wearing it at wrong locations. Even a perfect radiological dosemeter will not measure anything, if the worker does not wear it. During intercomparisons the dosemeters are fixed in 104anada104g104d104n ways to a phantom. In reality, they are worn on different parts of the body. Therefore, more effort should be given to the ergonomics of the dosemeters. Especially for extremity dosemeters and eye lens dosemeters, the users feel very uncomfortably in wearing them during their job. Another example is the albedo dosemeters. If they are worn in a vest pocket that is 10 cm away from the body, they will seriously underestimate the Hp(10) dose, because it is designed to measure the backscattered neutrons. Another challenge is that the present extremity dosemeters do not measure the maximum dose on the hands, but just at one point, often far away from the maximum (for example wrist dosemeters) [6]. Too little is still known on all the correction factors that should be applied for wearing the dosemeters on different locations of the hand.

If feedback is given to the workers on their dosemeter results, it could improve the way workers use their dosemeters. This can be achieved by active dosemeters, they can help to improve the ALARA-principle on the workplace. In many workplaces, both an active dosemeter and a passive dosemeter are required. For some years the discussion is on-going to use only the APD, and no longer a passive dosemeter. A study from EURADOS [7] showed that the APD's have achieved a technological level that is similar or even better than the passive dosemeters. Also the level of reliability has become comparable or even better than for passive devices. For example, when a dosemeter reading gets lost from a passive device with monthly read-out, much more information is lost than in case of an active dosemeter with daily read out. However, it must not be forgotten that some APDs have a reduced response to pulsed fields [6]. Some countries allow active dosemeters as the only dosemeter to be used during working practice. In that case it is important that a quality assurance system is carefully installed and that regular quality control checks and calibrations are performed. Approval by the national authorities will also be required, and in general, a dosimetry service still has a role to play in this issue.

Some recent devices, like those based on the DIS technology, can be 104anada104g104d104 in between passive and active dosemeters. These types of dosemeters do not give an alarm, and do not visually display the dose received. But the worker can consult the results at any chosen time. In the newest devices communication between the dosemeter and a computer or iPad is possible. No longer is any read-out by a dosimetry service needed, and the dosemeter has a quite long battery life. It still needs to be proven that these dosemeters fulfil the radiological requirements of the IEC standards, and also the quality assurance and calibration will need to be regulated. But not having to return the dosemeters for read-out is certainly a big step forward in improving the practical acceptance of personal dosimetry. It is clear that many future dosemeters will follow this trend.

An additional advantage of active personal dosemeters is their lower reporting level. Many devices show doses down to 1 μSv, or even to 0.1 μSv. Most passive dosimetry systems have reporting levels of 50 to 100 μSv per month. However, care should be taken not to confuse both numbers. The dosemeter indication will give the gross dose, also known as the measured value. The gross dose will include a contribution from the natural (radiation) background in addition to any dose from the worker's occupational radiation exposure. This background radiation needs to be subtracted from the measured value. When dosimetry services report a dose, the background is already subtracted, when a worker reads out his APD, this is generally not the case.

The ICRP has also prescribed a minimum value for the recording level, i.e., the dose above which recording of the doses should be required. It is stated that:

> "The Commission now considers that the recording level for individual monitoring should be derived from the duration of the monitoring period and an annual effective dose of no lower than 1 mSv or an annual equivalent dose of about 10% of the relevant dose limit." [1].

For a monthly exchange this give a minimum recording level of 83 μSv per month or 5 μSv for a daily read out (1 year = 200 working days). These are values with the background already subtracted.

Background values can typically be between 1.5 and 3.0 μSv/day, depending on the underground, the altitude, the building material, etc. For a monthly exchange, this means that between 90 and 180 μSv need to be subtracted from the measured value (60 days inbetween readings of the passive dosemeter). If a national average is taken of e.g., 130 μSv, than all doses lower than 50 μSv can be caused by variation of the background. So the lower limit of detection (LLD) will not be better than minimum 60-70 μSv per month for a dosemeter with a good sensitivity. If a specific background per customer is used, this can be lowered to about 30-40 μSv/month, depending on the way and accuracy of background determination. Also for APDs a background subtraction is needed, and the local background should be known. In case of an APD the amount of background radiation depends of course on how many hours the APD was active. If the APD is only switched on during the day (like only when entering the zone), the lower detection limit is much better than for passive dosemeters (with the same background assumptions as above): about 0.4 μSv per day without exact knowledge of the background, and about 0.2 μSv per day with good background knowledge. This means that for APDs the detection level is much lower than the requirements from ICRP, while for passive devices it is more a challenge to get to these values. But, even though the active devices might become more and more sensitive, how low the doses are that can be measured is limited by this background fluctuation.

CONCLUSIONS

What will the future bring? How will a dosemeter look in 20 years from now? Probably for many people they will still look the same as today. Many dosimetry services fulfil the ICRP requirements, are cost effective and thus do not need any further improvements. It is clear from the intercomparisons that in general the personal dosimetry services perform a good job in estimating Hp(10) with their dosemeters. Therefore, the question could be asked if it is not needed to decrease the performance limits from the ICRP. This would encourage the dosimetry service to do extra efforts to improve their dosemeters, especially for energy and angular dependence. Better radiation response characteristics of the dosemeters would not drastically improve the risk estimation, but it will help in improving the trust that workers have in their dosemeters by getting lower uncertainties. It must be noted though that not in all parts of the world the dosimetry services follow ISO17025 yet, and in many developing countries, the quality of the dosimetry services can still be improved.

There are still problems to be solved, notably better neutron personal dosemeters, a better response to low beta radiation, and to pulsed field in case of APDs. Better ergonomic solutions should also be found for eye lens and extremity dosimetry. In case of inhomogeneous fields, like for example when the worker is wearing a lead apron, there is currently no good approach to estimate the effective dose. The double dosimetry method (one dosemeter above and one below the lead apron) can give very different results depending on the algorithm used to combine the measured values from both dosemeters.

The future trend will certainly be to use more frequently active dosemeters, or at least dosemeters that can be consulted whenever the user wants. This direct feedback is important for ALARA purposes. Variation in the background doses make that it is not needed to have even more sensitive devices.

It could also be discussed whether Hp(10) is the best quantity to be measured in personal dosimetry. There are some developments in trying to image DNA lesions. Such measurements might give a better link with the real risk. If we can imagine that in the future dosemeters will measure directly DNA damage, dosemeters might not be needed anymore. Maybe some small reader device will be able to image DNA damage directly in the body of the worker? Such dosemeters would automatically take into account individual variations in radiation sensitivity.

Another possible evolution for the future might be that more and more computational methods will be used. At the moment doses to all organs can be simulated with Monte Carlo methods, once the radiation field is known. This can even be done in personalized phantoms. As computational power increases, it could be possible that such simulations may be done on-line. This would imply that there is no need to wear any dosemeter and it would be possible to determine the doses to all organs at risk, even in complete inhomogeneous fields.

To conclude, even though the present dosimetry systems fulfil the requirements of the ICRP, improvements in the dosemeters, and even new and exciting evolutions can still be expected.

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THE STATUS AND CHALLENGES OF INTERNAL DOSIMETRY (TECHNICAL ASPECTS)

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Abstract

The internal dosimetry community dealing with occupational exposures is focused on (1) the harmonization of methods and tools to obtain the "best estimate" of the intake and dose due to the incorporation of radionuclides into the body (forthcoming ICRP Reports on "Occupational Intakes of Radionuclides" (OIR) and on "Public Intakes of Radionuclides", IDEAS Guidelines, EC BSS and Technical Recommendations, IAEA Safety Guides), (2) normalization of the establishment of ISO Standards that guarantee reliability of the results of monitoring and dose E(50) and permit accreditation of internal dosimetry laboratories (3) Networking and coordination of research to promote collaboration of internal dosimetry experts (European Dosimetry Group EURADOS, PROCORAD Association for in-vitro monitoring, WHO REMPAN WG on internal dosimetry) and (4) education and training (IAEA, ENETRAP, EURADOS). Main challenges identified are the implementation of the new OIR biokinetic models, the accreditation of internal dosimetry services according with ISO17025, the improvement of individual monitoring and dose assessment in case of R/N emergency, the application of new tools such as Monte Carlo methods and voxel/NURBS phantoms for in-vivo monitoring, the improvement of biokinetic models to study non-cancer effects and the dosimetry of medical staff exposed to internal exposures.

INTRODUCTION

Doses from internal radiation exposures cannot be measured directly, but must be assessed from individual monitoring data such as the activity content (Bq) of radionuclides in the body or by the determination of excretion rates (Bq/day), using in-vivo and in-vitro techniques respectively, from workplace monitoring of the activity concentration of the activity in the air (Bq/m^3) or by a combination of individual/workplace measurements.

The interpretation of monitoring data for the calculation of the Intake I (in Bq) and Committed Effective Dose E(50) (in mSv) require the application of biokinetic and dosimetric models, and the assessor has to make assumptions about the mode (acute, chronic), pattern (inhalation, ingestion, wound, injection) and time of the intake, about the physical (particle size) and chemical characteristics of the radioactive material incorporated, and the elapsed time between the exposure and the measurement.

The Annual Dose Limit for a radiation worker's effective dose (internal + external exposures) is generally established of 20 mSv/year by regulators. As a general approach monitoring programs of internal exposures should guarantee the detection of all the doses above 1 mSv/year due to intake of radionuclides at workplace (unless the sensitivity of the technique makes it not possible, e.g. measurement of Actinides).

CURRENT STATUS OF DOSIMETRY OF OCCUPATIONAL INTERNAL EXPOSURES

The Internal Dosimetry community dealing with occupational exposures is currently focused on:

(1) The harmonization of methods and tools to obtain the "best estimate" of the intake and dose due to the incorporation of radionuclides into the body (ICRP, IDEAS Guidelines);
(2) Normalization for the establishment of Standards for appropriate quality assurance programs that guarantee reliability of the results of monitoring and dose E(50) and permit accreditation of internal dosimetry laboratories (ISO, ICRU);
(3) Networking and coordination of research to promote collaboration of internal dosimetry experts and services (EURADOS, PROCORAD, WHO); and
(4) Dissemination of knowledge, education and training (IAEA, ENETRAP, EURADOS).

— International Commission on Radiological Protection (ICRP)

ICRP provides biokinetic and dosimetric models and data intended for the assessment of internal doses due to intakes from workers and public, in a series of publications. The forthcoming ICRP Reports on "Occupational Intakes of Radionuclides" (OIR), and the planned reports on "Public Intakes of Radionuclides" will provide updated biokinetic models and dosimetric tools that will replace ICRP 30 series, and ICRP publications 54, 68 and 78.

The 2007 Recommendations introduced changes to the radiation and tissue weighting factors used in calculation of effective dose. In addition, Publication 103 clarified the need for separate calculation of equivalent dose to males and females and sex-averaging in the calculation of effective dose and adopted the use of ICRP reference anatomical computational phantoms, in place of the mathematical models that have been used previously. These substantial changes implied a revision of the dose coefficients for internal exposure.

OIR Reports will provide revised dose coefficients for occupational intakes by inhalation and ingestion calculated using the ICRP100 Human Alimentary Tract Model (HATM) and a revision of the Publication 66 Human Respiratory Tract Model (HRTM) which takes account of more recent data. Revisions have been made of many models for the systemic biokinetics of radionuclides absorbed to blood, making them more physiologically realistic representations of uptake and retention in organs and tissues and of excretion. The reports provide also some guidance on monitoring programs and monitoring data interpretation.

Regarding the planned Public Intakes of Radionuclides" report, ICRP is developing a new family of age-dependent voxel phantoms based on work by the University of Florida: new-born, 1-year-old child, 5-year-old child, 10-year-old-child, 15-year-old female, and 15-year-old male. These phantoms add to the already existing adult reference male and female phantoms. Also a phantom of a pregnant woman at 8 different stages of gestation is being developed to calculate doses to foetus.

— International Organization for Standardisation (ISO)

ISO has published three standards on internal dosimetry developed by ISO TC85 "Nuclear Energy" /SC2 "Radiation Protection" / WG13 "Monitoring and dosimetry for internal exposures":

- ISO28218"Performance Criteria for radiobioassay" provides guidance on performance of radiobioassay service laboratories including criteria for quality assurance and control, and establishes a consensus on the statistical definitions and formulations of the quantitative performance criteria of (1) decision threshold and detection limit (sensitivity of methods) and (2) relative bias and repeatability (accuracy of results). Recommendations are presented on performance criteria for in vivo radiobioassay (identification of radionuclides, quantification) and for in-vitro radiobioassay (analytical methodology) with requirements for reporting and recording.
- ISO20553 " Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material" specifies the requirements for the design of programs to monitor workers exposed to the intake of radioactive substances at the workplace. This standard establishes principles for the development of suitable individual monitoring programs, so that appropriate decisions are taken on the choice of monitoring techniques and frequency of measurements taking into consideration the potential intake scenario (e.g. taking into account detection limits of available in-vivo and in-vitro methods of internal dosimetry service laboratories).
- ISO27048 "Dose Assessment for the monitoring of workers for internal radiation exposure" provides guidance for the interpretation of monitoring data of workers exposed to internal exposures to estimate the Intake I(Bq) and the Committed Effective Dose E(50) mSv. Most of the monitoring results indicate minor if not negligible occupational exposures; in these cases, while it is important to ensure the reproducibility of dose assessments it is also important to optimize the effort and cost involved in the evaluation. In the case of a significant intake, an exhaustive investigation is justified to assess the dose as reliably as possible. ISO27048 establishes standard procedures for internal dose evaluation from monitoring data to guarantee consistency and reliability in the results of Intake and E(50). This standard will help service laboratories for certification, accreditation or approval by authorities, which is a growing demand.

— 2.3 European commission (EC): the BSS and technical recommendations on internal dosimetry

European Council Directive 2013/59/EURATOM of 5 December 2013 lays down the basic safety standards for protection against the dangers arising from exposure to ionizing radiation. It is the new BSS (Basic Safety Standards) and Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 6 February 2018.

The EC-DG ENER project TECHREC is currently in progress, and will provide "Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides" (Contract Number: ENER/2014/NUCL/SI2.680087). This action started on 12 May 2014 and will end in May 2016. The contractors are EURADOS, (European Radiation DOSimetry Group e.V.) and 7 other institutions from European Union countries, with contributions from a total of 11 experts. The purpose of TECHREC is to provide guidance to the relevant authorities and public and private organizations on those aspects of the implementation of the EU Council Directive 2013/59/Euratom that are directly related to individual monitoring of internal exposures, and to foster harmonization.

Important issues being addressed by TECHREC include dosimetric and operational quantities, biokinetic and dosimetric models, methodologies for the assessment of intake and dose, methods for individual and workplace monitoring, design of individual monitoring programs, dose assessment in practice, wound dosimetry, dose assessment in the event of decorporation therapy, accuracy requirements and uncertainty analysis, quality assurance and quality control, accreditation/certification according to ISO/IEC standards, participation in intercomparisons, requirements for internal dosimetry services. Separate annexes address radon dosimetry for workers, internal dosimetry for workers after a major accident at a nuclear facility and internal dosimetry for assessment of risk to health.

An important task of this project is to identify stakeholders and invite them to provide comments on the drafts of the Technical Recommendations. Contacts have been established with the relevant national and international organisations including dosimetry and radiation protection services and associations and regulatory bodies. The Final Report on the Technical Recommendations will be open access for the internal dosimetry community from the European Commission web site.

— 2.4 European Radiation Dosimetry Group — EURADOS

EURADOS is a European 112anada112g112d112n of 61 laboratories and institutions (Voting Members) and more than 500 Associate members involved in the field of the dosimetry of 112anada112g radiations. Working Group 7 (WG7) within EURADOS acts as a network of scientists, services, regulators and laboratories collaborating for the coordination of research and the dissemination of knowledge for the assessment of doses due to intakes of radionuclides. WG7 has established contacts with international organisations and associations in different European countries and also from outside Europe (America and Asia). Formal collaboration is ongoing with USTUR (U.S. Transuranium and Uranium Registries) to share autopsy and dosimetric data of U.S. workers exposed mainly to Uranium, Plutonium and Americium. Collaboration with NIRS-Japan (National Institute of Radiological Sciences) was established in relation to the reconstruction of early internal doses of population in the TEPCO Fukushima Daiichi NPP accident. EURADOS WG7 "Internal Dosimetry" program of work is presented as follows:

(1) Harmonization on internal dose assessments (e.g. IDEAS Guidelines);
(2) Implementation and Quality Assurance of Biokinetic Models;
(3) Individual monitoring of internal exposures and application of Monte Carlo (MC) methods and voxel phantoms to in-vivo monitoring (collaboration with WG6 "Computational Dosimetry");
(4) Education and training on internal dosimetry (e.g. Fundamentals, MC for in-vivo monitoring…);
(5) Microdosimetry of internal emitters; and
(6) Study of biological dosimetry vs. internal dosimetry in cases of accidental internal exposures.

— IDEAS Guidelines ver.2: Estimation of Committed doses from Incorporation monitoring

Data was published as open access EURADOS Report 01-2013. Intercomparison exercises on internal dose assessments in the past have shown a wide range in the results of estimated doses provided by the participants, obtained from the same monitoring data set, depending on assumptions of the exposure scenario and the biokinetic and dosimetric models applied, and hence the need for guidance on 113anada113g113d113 evaluations. IDEAS Guidelines are based on a general philosophy of:

- Harmonisation: any two assessors should obtain the same estimate of dose from a given data set;
- Accuracy: the "best" estimate of dose should be obtained from the available data; and
- Proportionality: the effort applied to the evaluation should be proportionate to the dose.

IDEAS GL use a "Levels of Task" to structure the approach to a E(50) evaluation: Level 0 (annual doses < 0.1 mSv, no dose evaluation required); Level 1 (Simple evaluation using ICRP reference parameter values (typical dose: 0.1 – 1 mSv); Level 2: advance evaluation using additional information as a result of an investigation for a more realistic assessment (typical dose: 1- 6 mSv) and Level 3: more sophisticated evaluation by an expert (typical dose > 6 mSv).

— Intercomparison of monitoring internal emitters – PROCORAD association

PROCORAD is a European organization of laboratories dealing with in vitro measurements of radionuclides in excreta samples. The main activity of this group is the 113anada113g113d113n of regular intercomparisons (IC) of measurements to promote fruitful scientific and technical exchanges between its members. A scientific meeting is organized each year during the Association's General Assembly, alternately in France and abroad. A technical report is published each year in French and in English. Laboratories from Europe and from outside Europe are regular participants of this exercise.

— IAEA – draft safety guide on occupational radiation protection

The draft safety guide on occupational radiation protection (DS453) is prepared based on the revised international basic safety standards. It combines all the relevant safety guides on the protection of workers into a single comprehensive safety guide, including the existing Safety Guide RS-G-1.2 Assessment of Occupational Exposure due to Intakes of Radionuclides (1999), which will be superseded once the draft is approved for publication.

FUTURE CHALLENGES TO IMPROVE INTERNAL DOSIMETRY OF WORKERS

Exposure of medical staff: The ISO TC85/SC2/WG13 is developing a new standard (ISO 16637, DIS 2014) to deal with monitoring and internal dosimetry for staff exposed to medical radionuclides as unsealed sources.

Accreditation of internal dosimetry services and laboratories according to ISO17025: The aim of the accreditation of internal dosimetry laboratories and services is to guarantee technical competence for (1) monitoring of radionuclides incorporated in the body and (2) evaluation of Committed Effective Dose E(50) mSv. The international standards dealing with internal dosimetry should be taken into account in the accreditation process (ISO2818, ISO27048 and ISO20553).

World Health Organization (WHO)/ Radiation Emergency Medical Preparedness and Assistance Network (REMPAN): The WHO REMPAN Internal Contamination Working Group was recently established with the aim to conduct collaborative projects to fill the knowledge gaps in emergency population monitoring, internal radiation dose assessment and medical management of internal contamination.

EURADOS Strategic Research Agenda and synergies with other Radiation Protection Networks: The European platforms on radiation protection MELODI (Multidisciplinary European Low Dose Initiative), the European Radioecology ALLIANCE, NERIS (European Platform on preparedness for nuclear and radiological emergency response and recovery) and EURADOS (European Radiation Dosimetry Group) have signed a Memorandum of Understanding (MoU) to confirm their joint commitment towards the consolidation and implementation of a strategic vision for radiation protection research in Europe. EURADOS has developed its own Strategic Research Agenda (SRA) with links and synergies with the other MoU Platforms. Important topics for research on internal dosimetry and challenges for the near future are presented as follows:

- To implement a more physiological approach to biokinetic models to allow the study of non-cancer effects, e.g. vascular diseases, by including blood as compartment in the biokinetic models;
- Lessons learned after the Fukushima Daichi NPP accident: to improve individual monitoring and dose assessment in case of RN emergency, including more rapid methods for in-vitro monitoring (e.g. alpha emitters), risk communication and management of the emergency situation;
- Monte Carlo calibration of Body Counters using voxel/NURBS phantoms;
- EURADOS Report as Guide for the implementation of new ICRP/OIR Biokinetic Models;
- EURADOS Dose Assessment Intercomparison after publication of TECHREC and OIR reports.

REVISION OF ISO 15382—ANSWERS TO THE CHALLENGES OF MONITORING DOSES TO THE LENS OF THE EYE

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Abstract

In April 21, 2011, the International Commission on Radiological Protection (ICRP) has reviewed its recommendation about the equivalent dose limit for the lens of the eye to "20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv". This new limit which replaces the old limit of 150 mSv in a year, is very challenging in term of radiation protection but also in term of specific dosimetry which becomes necessary and need to be done with more accuracy for more situations than in the past. The main objective of the revision of the 15382 standard "Procedure for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation" issued in April 2002, is to take into account this new situation, as illustrated with the new title of the document "Procedures for monitoring the dose to the lens of the eye, the skin and the extremities". The new document aims also to capitalize on the results of the last works on the subject and to be a starting and practical reference to help stakeholders to set up lens of the eye, skin and extremities dose monitoring.

INTRODUCTION

In its statement on tissue reactions approved on April 21, 2011, the International Commission on Radiological Protection (ICRP) has reviewed its recommendation about the equivalent dose limit for the lens of the eye [1]. The new recommendation is then: "For occupational exposure in planned exposure situations the Commission now recommends an equivalent dose limit for the lens of the eye of 20 mSv in a year, averaged over defined periods of 5 years, with no single year exceeding 50 mSv". The previous limit was set in 1990 in ICRP publication 60 [2]. The limit, set to protect against non-stochastic effects, for workers was of 150 mSv in a year for the lens of the eye and of 500 mSv for other tissues. This new limit is very challenging in term of radiation protection but also in term of specific dosimetry, which becomes necessary and need to be done with more accuracy for more situations than in the past.

DISCUSSION

The present version of the ISO standard 15382 "Nuclear energy — Radioprotection Procedure" for radiation protection monitoring in nuclear installations for external exposure to weakly penetrating radiation, especially to beta radiation" was issued in April 2002. It gives recommendations and describes the procedure for monitoring the dose of workers for external exposure to weakly penetrating radiation. It deals with the question of lens of the eye monitoring. With the dose limits recommended at that time by ICRP, it was considered in the standard that: "For beta radiation with maximum energies E_{β},max < 3,5 MeV (ICRU 43) and for photons with energies E_{ph} < 10 keV, the ratio of dose equivalent on the skin surface to that at 3 mm depth is greater than 3,3, i.e., greater than the ratio of the annual limits recommended by ICRP for skin and the lens of the eyes. In these cases, the dose on the skin determines the limit. A partial-body dose determination for the lens of the eyes is therefore not required for the radiation specified above if the skin dose near the eyes does not exceed the dose limit".

The main objective of the revision of the 15382 standard, which considers all type of exposures except those due to alpha and neutron is to take into account the new situation largely due to the evolution of the ICRP recommendation but also to capitalize on the results of the recent works on the subject like notably those of the European project ORAMED "Optimization of Radiation protection for MEDical staff", a collaborative project funded in 2008 within the 7th EU Framework Programme, Euratom Programme for Nuclear Research and training [3]. It was also important to take into account the last standard references to be followed for type test characterization of the dosemeters [4-6].

Like its content, the title of the standard, "Radiological protection – Procedures" for monitoring the dose to the lens of the eye, the skin and the extremities" evolves to cover all the situations where individual monitoring of radiation exposure of the skin, extremities (hands, fingers, wrists, forearms, feet and ankles) and lens of the eye can be needed excepted situations of exposure to neutrons. Indeed the standard will cover practices which involve a risk of exposure to photons in the range of 8 keV to 10 MeV and electrons and positrons in the range of 60 keV to 10 MeV. It will provide procedures for monitoring the dose to the skin, the extremities and the lens of the eye.

The questions on which the standards will give guidance are:

- How to determine the need to use dosemeters;
- How to ensure that individual monitoring is appropriate to the nature of the exposure;
- How to design a monitoring program which ensure compliance with legal individual dose limits;
- How to choose the type of dosemeters (in an annex of which the content is adopted from the IAEA TecDoc No. 1731[1] "Implications for occupational radiation protection of the new dose limit for the lens of the eye" [7]);
- How to choose positioning of the dosemeters; and
- How, when it is needed, determine correction factors.

CONCLUSIONS

The overall objective of the new document is to be a starting and practical reference to help stakeholders to set up lens of the eye, skin and extremities dose monitoring adapted to the different situations of exposure.

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[4] IEC 60846-1, Radiation protection instrumentation — Ambient and/or directional dose equivalent (rate) meters and/or monitors for beta, X and gamma radiation — Part 1: Portable workplace and environmental meters and monitors.

[5] IEC 61526, Radiation protection instrumentation — Measurement of personal dose equivalents Hp(10) and Hp(0,07) for X, gamma, neutron and beta radiations — Direct reading personal dose equivalent meters (2010).

[6] IEC 62387, Radiation protection instrumentation — Passive integrating dosimetry systems for personal and environmental monitoring of photon and beta radiation, (2012).

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 2

S. Mundigl

European Commission

The session on dose assessment of occupational radiation exposures received a very high interest from the participants in the conference. In total, 35 contributed papers have been accepted by the reviewers and were presented as posters. The main areas covered by these papers can be categorized in three groups:

(1) Dosimetry of external exposure (26 papers);
(2) Dosimetry of internal exposure (6 papers);
(3) Programmes to monitor occupationally exposed workers (3 papers).

The largest group of papers on dosimetry of external exposure reported on progress with international guidance and standards, secondary standards dosimetry laboratories, development of dosemeters, type testing of dosemeters, mainly in pulsed fields, computational techniques, intercomparison exercises, and the specific issue of skin dosimetry in occupational exposures. Many papers (eight) discussed the new dose limit for the lens of the eye and issues with regard to the related eye-lens dosimetry. Session 2 has shown that the major challenges in dose assessment of occupational radiation exposures lies with the dosimetry in new medical procedures and techniques, in particular with regard to eye lens dosimetry and dosimetry in pulsed fields, and in internal dosimetry.

CHAIRS' SUMMARY OF TOPICAL SESSION 2

The importance of harmonized units and dose assessment methods to occupational radiation protection was emphasized in Session 2. The first presentation was on the status and emerging problems with the current system of radiation units. This was followed by presentations on external and internal dosimetry, with emphasis on new developments and challenges. The session ended with a presentation on a specific problem in dose assessment, the measurement of dose to the lens of the eye.

Mr. Menzel representing the International Commission on Radiation Units and Measurements, ICRU, pointed out that the use of the protection quantity effective dose had enabled the occupational radiation protection community to apply the optimization and limitation principles in such a way that the average annual effective doses and the annual collective doses in each planned exposure situation have decreased year after year.

Future work in the area of quantities and units were also presented. Operational Quantities for external radiation have been introduced 30 years ago and are facing limitations and restrictions in their application at high radiation energies and also due to conceptual difficulties (composition of ICRU sphere, depth in sphere). The dose coefficients for occupational intakes of radionuclides (OIR) following the ICRP 103 recommendations need to be evaluated and published. The radiation weighting factors are still based on a few, not always pertinent scientific data (RBE values). An open question is whether the quantity of equivalent tissue dose is suitable at high radiation doses. Currently an ICRU Committee is reviewing the definition of the operational quantities

In conclusion, the ICRP radiation protection quantities and related measurement quantities have proved to play a fundamental role for the implementation of the limitation and optimization principle. The complimentary role of ICRP, ICRU, IAEA (Basic Safety Standards), the EU and international standards organizations has led to an effective practical implementation of radiation monitoring and dose assessment in occupational exposure. Optimization using protection quantities has led to a substantial reduction of mean individual and collective doses.

Mr. Vanhavere made a presentation on external dosimetry and made a rapid summary of the available techniques. There is a world-wide tendency for external monitoring services to establish quality management systems, and for regulatory agencies to require authorization or certification of these services. The most complete quality management system is considered to be that following the guide ISO 17025. The result of additional quality requirements is additional costs to the services, which in turn has led to a reduction in the number of the services and the consequent increase in the number of occupationally exposed workers per service. This trend is likely to continue.

As to the measurement uncertainties, improvements in the dose calculation algorithms are always important. Intercomparisons are a key tool to demonstrate compliance with the performance requirements. For Hp(10), photons, the EURADOS intercomparisons show that the services can measure dose within the trumpet curves. However, these intercomparisons are usually limited to simple radiation fields, with no mixture of photon energies and angles. For extremity dose measurement and for neutron and beta dose measurement the situation is worse and further intercomparison exercises and improvements in the dosimeter design and algorithms should be undertaken.

As to the future, a possible narrowing of the performance requirements might be proposed. Improvements to neutron personal dosimeters and better response to low-energy beta radiation should be made. Active dosimeters should also become more commonplace in planned exposure situations. Computational methods for dose calculations will be more used in the future.

In Ms. Lopez-Ponte´s presentation on internal dosimetry the current status of internal dosimetry methods, international standard and guidelines, especially recent ISO standards were discussed. For harmonization and higher efficiency in measurement it turns out that networking and coordination of research is essential. Notable examples include the EURADOSE initiative, the CURE project, MELODI and OPERA.

The next few years in internal dosimetry will see further accreditation of internal dosimetry laboratories and services and the implementation of Occupational Intake of Radionuclides (OIR) publication on biokinetic models about to be published by the ICRP. The work on harmonization of methods and new and existing methods will continue, especially in Europe.

Main challenges identified in the frame of internal dosimetry are to continue the improvement in monitoring techniques, dose evaluation and management of people, samples and communication) in case of a radiological or nuclear emergency event. Further studies should be carried out on the internal dosimetry of medical staff at risk of intake of radionuclides. New tools are being applied for in-vivo monitoring of internal exposures such as Monte Carlo calibration using voxel or NURBS phantoms. Networking and multidisciplinary research projects should continue such as the CURE Project "Concerted Action for an Integrated (biology – dosimetry – epidemiology) and Research project on Occupational Uranium Exposure". More realistic biokinetic models for the study of non-cancer effects of internal exposures including radiopharmaceuticals should be developed.

Mr. Queinnec made a presentation on the current status of eye lens dosimetry. The subject has received renewed attention due to the recommended lowering of the annual dose limit by the ICRP. A summary was made of the workplaces where the eye lens dose is of importance. The revision process and objectives of standard ISO 15382 "Radiological protection — Procedures for monitoring the dose to the lens of the eye, the skin and the extremities" were described. Photon exposures (8 keV–10 MeV) and electron/positron exposures (60 keV – 10 MeV) are taken into account.

More services are supplying dosimeters for Hp(3). EURADOS is organizing and intercomparison, however, further intercomparison initiatives are welcome. Most monitoring is performed with passive dosimeters, but active dosimeters using small silicon detectors, may also be used.

The Session 2 ended with the Mr. Mundigl's summary of the contributed papers. A high interest in this session was reported, a total of 35 papers were accepted. The main areas covered were external exposure dosimetry (26 papers), extremity and eye-lens dosimetry (9 papers), internal exposure dosimetry (6 papers), development of dosimeters (4 papers), testing of dosimeters (4 papers) and intercomparison exercises (4 papers). Some challenges were identified in the areas of dosimetry in new medical procedures and techniques, eye lens dosimetry and dosimetry in pulsed fields.

TOPICAL SESSION 3:

RADIATION EFFECTS AND HEALTH RISKS FROM RADIATION EXPOSURE AT THE WORKPLACES

Chairpersons: F. Gobba, Italy and M. Crick, UNSCEAR

RADIATION EFFECTS AND HEALTH RISKS FROM RADIATION EXPOSURE AT THE WORKPLACES

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Abstract

The Ionizing radiation has the potential to cause various health effects. Among others: skin burns, epilation, sterility, cancer, leukaemia, cataracts, circulatory diseases, malformations, and mental retardation. For practical reasons those effects are divided as far as possible into deterministic and stochastic in radiation protection. In particular, cancer, cataracts and circulatory diseases are very frequent, so that workers who are occupationally exposed to ionizing radiation will be diagnosed with those health problems quite often. In a number of cases the question is put forward, whether the health problem was caused by radiation. The answer is sometimes very difficult to give.

INTRODUCTION

Ionizing radiation can be responsible for a number of health effects:

- Effects like skin burns, epilation, malformations or sterility, which are due to cell death or malfunctioning of many cells, so-called deterministic effects or tissue reactions;
- Effects like cancer or leukaemia, which are caused by modifications, in particular of the genome, that are compatible with survival of the cells. These are called stochastic effects.

This distinction is quite useful in radiation protection, because deterministic effects only occur after exceeding a dose threshold (in most cases in excess of one gray) and, thereafter, the severity of the effect increases with increasing dose. This is different for stochastic effects, because in radiation protection it is assumed that there is no threshold and that the number of people affected increases with increasing dose (the so-called LNT concept, linear non-threshold).

This very pragmatic categorization, however, is not without problems. At a moment, for example, it is not possible to decide whether cataracts and circulatory diseases are of a deterministic or a stochastic nature or neither of these. The same applies to some radiation effects during pregnancy (e.g. induction of malformations during the early preimplantion period observed in some mouse strains or IQ reduction). A serious problem is that nobody knows whether LNT is correct. We do know that a statistically significant increase of malignancies (cancer and leukaemia) can be observed in populations of several ten thousand individuals after about 100 mSv [1], and in extensive studies of foetuses after exposure of about 10 mSv [2]. Below these doses the situation is far from clear. We only know that the risk (i.e. the number of people affected during lifetime) must be so low that it cannot be detected with current methods. Even the possibility that a threshold dose and protection against spontaneously occurring malignancies exist somewhere in the low (below 100 mSv) or very low (below 10 mSv) dose range cannot be excluded with certainty.

RADIATION INDUCED HEALTH EFFECTS AT THE WORKPLACE

It is evident that workers occupationally exposed to ionizing radiation can run into health problems. Frequently, the question emerges whether a specific health problem was caused by radiation.

Due to the system of dose limits in radiation protection, deterministic effects cannot occur as long as the dose limits are obeyed. Thus, such effects can only happen in the case of accidents. Unfortunately, as to be observed at all workplaces, severe accidents cannot be completely ruled out. Fortunately, those situations are comparatively rare at workplaces [3] but they demonstrate that detailed and from time to time reiterated safety instructions are essential.

Malignancies are frequent. Almost half of all people will develop either a cancer or a leukaemia during their lifetime. Thus, it is no surprise when a worker, who was employed in a radiation-exposed occupation, is diagnosed with a malignancy. How claims are handled that radiation exposure at the workplaces was responsible will be dealt with in this chapter. During recent years, the view on radiation-induced cataracts has changed markedly [4] [5]. Originally, cataracts were supposed to be of the deterministic type with a threshold after chronic exposure of more than 5 Gy. A number of studies have shown that this view is not correct. If a threshold exists at all, then it is, at least, about tenfold lower [6]. This has prompted ICRP to suggest a reduction of the dose limit per year from 150 mSv to 20 mSv for the lens of the eye of workers. Due to still lacking data on age and gender risk after radiation exposure [7], it is very difficult to almost impossible to decide whether an observed cataract is caused by radiation exposure at the workplace. Clearly more data are necessary.

Another still unresolved problem is the observation that circulatory diseases are not restricted to high doses as thought in the past. Definitely, more data are necessary, before final conclusions can be drawn, but circulatory diseases after radiation exposure at the workplace are an issue that has to be kept in mind [8–11].

A group of individuals that needs specific attention is an unborn child, meaning that the female worker should be aware that, in particular, during pregnancy lower dose limits are effective. In addition, in some countries uterus dose per month is specifically limited. There are four major health effects observed in embryos/foetuses: death, malformations, mental retardation and malignancies. Mortality is especially high during the first two weeks of gestation, three to seven weeks are characterized by malformation risk, and eight to fifteen weeks, and with a somewhat reduced sensitivity sixteen to twenty-five weeks, show an increased risk of mental retardation. All stages may be affected by an increased risk of malignancies, in particular, leukaemia. The latter health effect is the major reason why the unborn child needs specific radiation protection, because a statistically significant increase in risk is seen above about 10 mSv [12] and the other effects mentioned above have thresholds in excess of, at least, 100 mSv. An exception might be IQ reduction after radiation exposure in the weeks eight to twenty-five, because it is not clear whether there is a threshold or not; in any case, however, a possible IQ reduction after low doses is so low that it cannot be detected.

ATTRIBUTION, INFERENCE AND UNCERTAINTY

As outlined above, radiation-induced health effects can occur at workplaces. Frequently, it is very difficult to decide whether a specific health effect can be attributed to ionizing radiation. The major obstacle is the lack of a biomarker that signals that radiation was responsible for the observed health effect. The situation, however, is comparatively easy for deterministic effects. On the one hand, they do not occur below a certain threshold and this threshold is rather high (in excess of about 1 Gy for adults and of about 0.1 Gy for the foetus). On the other hand, deterministic effects have so many specific characteristics that attribution is usually very convincing. This is dramatically different for stochastic effects. Of course, one can attribute malignancies to radiation exposure in a population given that the population consists of many individuals and the doses are high enough and specifically for workplaces [12].

The problem is the individual attribution that is, of course, relevant when it comes to compensation claims. Due to the lack of a biomarker, the only possibility to assign this specific malignancy to radiation is the estimation of the probability that this health effect was caused by radiation. The probability is based on the probability seen in populations and the procedure is coined "probability of causation" or, more precise, but less catchy, "assigned share". In various countries various concepts are used for compensation [13], but almost all of them are somehow based upon "assigned share".

CONCLUSIONS

Inference of risk in the low and very low dose range in the sense of a prediction of future stochastic health effects in a strict scientific sense is not possible. The reason for this has already been outlined in the Introduction: we just do not know what will happen to the general public after doses well below about 100 mSv. We do know, however, the risk must be low, because otherwise we would have seen it in epidemiological studies in the past. Therefore, with a few exceptions, it does not make sense to calculate numbers of cases of death based on the multiplication of low doses or, in particular, very low doses and the number of individuals affected. The few exceptions refer to the necessity to compare risks in some situations. One should bear in mind, however, that the results of those calculations are only notional and do not necessarily imply that these calculated cases are real. What has to be considered, in addition, and what makes the situation even more complicated is the uncertainty of scientific results. This very complex problem is dealt with in an UNSCEAR publication that will be published soon.

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SCIENTIFIC AND EPIDEMIOLOGICAL BACKGROUND FOR RADIATION RISK OF THE LENS OF THE EYE

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Abstract

In April 2011, the International Commission on Radiological Protection (ICRP) released a statement that drastically reduced the recommended threshold values for human radiation cataractogenesis to 0.5 Gy from previous values of 2-8 Gy. At the same time, recommended occupational lens exposure limits were lowered from 150 mSv/yr to an average of 20 mSv/yr over 5 years, with no single year exceeding 50 mSv. These recommendations were based, in part, on recent findings of significant radiation cataract risk at low levels of occupational 127 anada 127 g radiation exposure by medical professionals engaged in interventional procedures. These new recommendations have significant implications for human ocular health risks following occupational exposures and highlight a pressing need to better estimate risk of radiation-induced lens pathology. These new recommendations are also likely to affect radiotherapy and diagnostic protocols as well as hypotheses regarding radiation cataract pathomechanisms.

INTRODUCTION

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 [1]. This view was, in part, based on 50-year-old observations of accidentally exposed individuals or radiation therapy patents with relatively small numbers of subjects with exposures below 2 Gy [2, 3]. Their ability to quantify early, radiation-associated lens changes was limited by methodological approaches which failed to take into account the fact that at lower doses, lens changes take years to progress to true visual disability [4]. 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 radio-therapeutic procedures, strongly suggest dose-related lens opacification at significantly lower levels of exposure [5]. These observations resulted in a re-evaluation of lens occupational exposure guidelines by the International Commission on Radiological Protection (ICRP) and a new recommendation to lower the presumptive radiation cataract threshold to 0.5 Gy [6]. This statement was also accompanied by a greatly reduced recommended occupational exposure limit for the lens of 20 mSv/yr regardless of whether it was received as an acute, protracted or chronic exposure.

Over the past 15–20 years, epidemiological investigations in a diverse range of individuals and settings, including occupational, therapeutic and accidental exposures, strongly suggested radiation-associated lens changes and ensuing visual disability occur at significantly lower doses than previously suspected and that, furthermore, given sufficient latency, chronic, prolonged and acute exposures result in similar pathological outcomes [7–12]. More recently, epidemiological studies of occupational ocular radiation exposure among medical professionals involved in interventional radiology and cardiology identified significant risk for radiation cataract in these workers [13–16]. These publications measured occupational eye doses in catheterization laboratories and the prevalence of radiation associated lens changes associated with such exposure. Detailed dilated slit lamp examinations demonstrated a 2–3 fold increased prevalence of radiation associated lens changes among physicians who routinely perform fluoroscopically guided procedures relative to non-irradiated controls. Of note, nurses and technicians who assisted them also demonstrated lens changes consistent with occupational radiation exposure, albeit at reduced prevalence, due to lower cumulative exposures. While lower dose limits appear prudent and supported by a variety of epidemiological, biological and clinical data, additional eye and lens specific real-time dosimetry is needed to establish more reliable dose-effect relationships. The ICRP recommended decrease in the putative threshold dose for radiation cataract formation, regardless of whether exposure is acute, prolonged or chronic, has significant implications for occupational radiation exposure in medical personnel, as a cumulative 500 mSv ocular dose is well within the range of exposure expected during working life if proper radiation protection equipment such as ceiling suspended shields or protective eyewear is not utilized [17–19]. The impact of these new recommendations on the practice of interventional medicine is likely to be significant and will likely hopefully initiate a new culture of radiation safety and awareness to reduce the high prevalence of radiation-associated lens changes noted in recent surveys among those working in interventional sub-specialties.

Conventional dilated slit lamp examination of the lens provides a convenient, non-invasive approach to evaluate radiation-induced lens damage. Furthermore, the non-invasive nature of this examination facilitates repeated examination over time to measure both onset and progression of specific lens changes. On the other hand, the subjective nature of the examination provides little information about actual visual disability from the point of view of the patient. For that reason, contrast sensitivity testing may offer a truer measure of radiation cataract induced visual change [15]. Preliminary findings suggest that the type of lens opacity most strongly associated with radiation exposure, posterior sub-capsular cataract, is more strongly associated with decrements in contrast sensitivity that nuclear or cortical cataract [20, 21]. Preliminary studies in both human and animals support this assertion and suggest a dual approach might provide more information about potential visual disability than traditional slit lamp examination alone.

The epidemiological and clinical findings detailed above are supported by a variety of experimental data, including animal studies, which indicate radiation-induced genotoxic damage, leading to aberrant cell division and differentiation, is the likely initiating insult [22-25]. The lens of the eye is among the most radiosensitive tissues in the body [26]. As compared to other eye tissues, where ocular pathologies occur after acute or fractionated exposures of between 5-20 Gy [27], early radiation-induced lens changes thought to be predictive of future cataract development can be observed at 10-fold or lower doses.

The principal pathology of the lens is its opacification, clinically referred to as a cataract [28]. Cataract is the leading cause of blindness worldwide, especially in less developed countries, where surgical treatment is often unavailable [29,30]. At least 39 million blind and 285 million visually impaired individuals may be affected [31]. The only treatment for cataract is surgical removal, a procedure that accounts for a relatively large share of vision health care costs [32]. While there are three predominant forms of age-related cataract depending on their anatomical location in the lens, cortical, nuclear and posterior subcapsular cataract (PSC), the last form is the only one strongly associated with radiation exposure. Each cataract type is associated with differing risk factors, for example cortical cataract, the largest component of age-related opacities, is most strongly associated with sunlight exposure [33] whilst smoking increases risk for nuclear cataract [34], the second most common form. PSC, which comprises less than 5% of age-related cataract, is also associated with systemic steroid use [35], chronic uveitis [36] and some forms of diabetes [37]. It is thought to arise from aberrant division and differentiation of anterior lens epithelial cells, resulting initially in small punctate opacities and vacuole formation surrounding the lens posterior pole region [38]. In its later stages, these small focal regions coalesce to form a discrete opaque plaque at the rear of the lens, along its visual axis, which, due to its central position along the lens visual axis, can have a significant effect on visual function.

Some individuals who are at occupational risk for radiation cataract have expressed the opinion that this outcome is a relatively minor health concern because it is easily treated with minimal complications. This view is not surprising as all cataract surgery, including surgical treatment for radiation cataract, is viewed by many as an ophthalmological procedure with relatively low morbidity and mortality but with considerable overall economic cost, e.g., consuming more than 40% of overall U.S. ocular disease expenditures, (~ 5.1 billion dollars) in 1999 [39]. This point of view may be inaccurate. Available data suggests mortality following cataract surgery is roughly 0.1% [40,41]. Morbidity, defined both from an ophthalmological as well as medical standpoint, is considerably higher. Of particular concern to long term visual function, the combined post-surgical risk of cystoid macular edema [42], retinal detachment [43, 44], posterior capsule rupture [45] or significant vision loss may be as high as 2.5%. Of note, male gender and age under 60 years is associated with the highest risk for post-surgical retinal detachment. Less than ideal outcomes after cataract surgery are especially relevant for those occupational workers who require a high degree of visual acuity, contrast sensitivity and binocular vision, e.g. interventional physicians, and further inform the need for such workers to use available technologies to reduce radiation exposure to the eyes. Personal protective equipment (PPE) such as lead glass eyewear with side shields, lead glass face shields, and/or adjustable lead glass shields, when properly used, can provide the necessary protection to reduce exposure to the eye and thus risk of radiation cataract. From a monitoring perspective, measurement of equivalent dose to the lens of the eye should be performed with a dosimeter placed either at the collar level outside any radiation protective garment or near the eyes.

It should also be noted that, prior to documented clinical need for cataract surgery, there may be accompanying progressive decreases in visual acuity, contrast sensitivity and visual function that may negatively impact worker performance. There is anecdotal evidence that the decrement in contrast sensitivity associated with posterior subcapsular cataract, the type most closely associated with radiation exposure, is a more important factor in worker performance than frank changes in visual acuity. For example, interventional physicians may report difficulty in seeing fluoroscopic images well before documented acuity changes on eye exams. The combined morbidity and mortality risks of surgical correction of radiation-induced cataracts (≥2.5%) and the, as yet not quantified, risk of an at risk physician misdiagnosing or mistreating a patient because of loss of visual acuity due to the presence of an undiagnosed radiation cataract, greatly outweighs any cancer risk at equivalent doses.

In conclusion, recent epidemiological data indicates there may be significant risk for radiation associated lens changes in occupationally exposed workers at doses previously thought to be below the lens "threshold" for radiation cataract. This finding suggests an urgent need for better ocular radiation safety education and policy, with appropriate training and use of eye protection tools, as well as better occupational dosimetry. Potential risk for radiation cataract and associated visual disability may be greatly reduced by use of appropriate radiation protection devices such as leaded glassware and will further ensure the safety of workers.

Lastly, recent findings of a lowered putative threshold for radiation-induced lens opacification are likely to influence current research efforts and directions concerning the cellular and molecular mechanisms underlying this pathology. An interesting radiobiological consideration regarding lens exposure is that the high radiosensitivity of the lens, coupled with the ability to non-invasively quantify individual radiation associated lens changes over time, may prove experimentally useful in quantifying radiation exposures and response as well as providing a built-in biological dosimeter for estimating radiation exposure.

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EVIDENCE OF CARDIOVASCULAR DISEASE RISK IN THE WORKPLACE — A REVIEW

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Abstract

There is growing evidence that low-level exposure to ionizing radiation may increase the risk of cardiovascular disease. Some of this evidence comes from epidemiological studies of occupational exposure to radiation. A review of the studies of workplace exposure suggests that proper account must be taken of the influence of major background risk factors before a reliable interpretation of the findings can be made. Only when a detailed assessment can be conducted of the full range of epidemiological findings that include adjustment for background risk factors, together with an enhanced knowledge of potentially relevant radiobiological mechanisms, will appropriate inferences for the purposes of radiological protection be possible.

INTRODUCTION

It is well established that high acute doses of ionizing radiation increase the risk of cardiovascular diseases, i.e. blood circulatory system diseases, such as heart attack and stroke (see, for example, [1–7]). The evidence for this comes from the experience of the Japanese atomic-bomb survivors and of radiotherapy patients. The underlying radiobiological mechanism is believed to be primarily cell killing by high absorbed doses (typically, the doses received by tissues from whole-body doses >1 Gy) leading to tissue damage and a consequent raised risk of cardiovascular disease that is clinically manifest some years later. However, there is growing evidence to suggest a raised risk of circulatory disease at lower levels of exposure to radiation, implying that radiobiological mechanisms associated with low/moderate acute doses or low/moderate dose-rates may be producing an increased risk of cardiovascular disease. Currently, the framework of radiological protection set out by the International Commission on Radiological Protection (ICRP) [8] does not include radiation-induced risks of non-cancer somatic diseases, such as circulatory diseases in the exposed individual, at low-level exposures. Hence, it is of some importance to understand and correctly interpret the evidence for circulatory disease risk associated with low or moderate dose/dose-rate exposures to radiation to ensure that the risks arising from these lower-level exposures are appropriately assessed and (if necessary) incorporated into the scheme of radiological protection. This is of direct relevance to occupational exposure to radiation, and there exists evidence of increased circulatory disease risk in workforces that have been exposed to radiation. This article will review this evidence for the risk of radiation-induced cardiovascular disease in the workplace.

STUDIES OF OCCUPATIONAL EXPOSURE TO RADIATION

A number of epidemiological studies of the risk of circulatory diseases among groups of workers exposed to radiation have been conducted and reported. These studies have been reviewed in the literature, including by Little et al. [9], subsequently updated by Little [10]. Workforces that have been studied include nuclear industry workers, Chernobyl emergency workers, and uranium miners. The evidence from these occupationally exposed groups is 133anada133g133d in Table 1, which updates the studies considered by Little et al. [9] and Little [10].

TABLE 1. SUMMARY OF ESTIMATES OF EXCESS RELATIVE RISK OF VARIOUS CIRCULATORY DISEASES PER GRAY OF CUMULATIVE WHOLE BODY EXTERNAL GAMMA DOSE

Workforce	Cohort size	Mean cumulative external dose (Gy)	Circulatory disease[a]	ERR/Gy (95% CI)
Mayak, Russia [11]	18 856	0.593	IHD incidence	0.16 (0.09, 0.23)
			IHD mortality	0.04 (-0.03, 0.11)
			CeVD incidence	0.53 (0.42, 0.64)
			CeVD mortality	0.06 (-0.04, 0.17)
15 countries [12]	275 312	0.021	CVD mortality	0.09 (-0.43, 0.70)
NRRW-3, UK[b] [13]	174 541	0.025	CVD mortality	0.25 (-0.01, 0.54)
BNFL, UK[b,c] [14]	38 779[d]	0.057	CVD mortality[e]	0.65 (0.36, 0.98)[f]
France[b] [15]	59 021	0.023	CVD mortality	0.31 (-0.90, 1.74)[f]
ORNL, USA[b,g] [16]	14 095	NA	IHD mortality	-2.86 (-6.90, 1.18)
Russian Chernobyl liquidators [17]	61 017	0.109	CVD incidence	0.18 (-0.03, 0.39)
Eldorado uranium miners, Canada [18]	16 236[d]	0.052	IHD mortality[h]	0.15 (-0.14, 0.58)
			CeVD mortality[h]	-0.29 (<-0.29, 0.27)
German uranium miners [19]	58 982	0.041	CVD mortality	-0.13 (-0.38, 0.12)

CVD = cardiovascular disease; CeVD = cerebrovascular disease; IHD = ischemic heart disease; NA = not available; CI = confidence interval

[a] Mortality data are based on underlying cause of death; [b] some overlap with 15-country study; [c] some overlap with NRRW-3 study; [d] men only included in analysis; [e] 15-year dose lag; [f] 90% CI; [g] analysis conducted in terms of the cumulative dose received after the age of 45 years; [h] 2-year dose lag.

Table 1 gives the summary of estimates of the excess relative risk (ERR, the proportional increase in risk compared to the background risk) of various circulatory diseases per gray of cumulative whole-body external gamma-ray dose, and associated 95% confidence intervals, obtained from studies of radiation workers. Results for all circulatory diseases combined are given, where available, or where not, major cardiovascular disease categories. Doses are lagged by 10 years, except where stated otherwise. Adaptation and update of tables presented by Little et al. [9] and Little [10].

DISCUSSION

Table 1 shows a general pattern of elevated excess relative risks of circulatory diseases associated with exposure to external sources of gamma radiation in the workplace, although a cautious interpretation is required. In particular, the significantly increased ERR/Gy for the workers of the former British Nuclear Fuels plc (BNFL), 0.65 (90% CI: 0.36, 0.98) [14], influences both the results of the third analysis of the UK National Registry for Radiation Workers (NRRW-3) [13] and the 15-country nuclear worker study [12]. Moreover, the results of the analysis of BNFL workers indicate that major background risk factors for circulatory disease, such as cigarette smoking and body mass index (BMI), need to be taken into account in any reliable interpretation of the findings. The standardized mortality ratio (SMR) for circulatory disease in male BNFL workers when compared to the general population of North West England is 0.84 (95% CI: 0.82, 0.86) [14], demonstrating a strong "healthy worker effect" and a broadly lower level of major background cardiovascular disease risk factors among this workforce than in the general population in the relevant region of the UK, an effect that is stronger for "white collar" male BNFL workers, SMR = 0.70 (95% CI: 0.67, 0.73), than for "blue collar" male BNFL workers, SMR = 0.89 (95% CI: 0.87, 0.91) [14]. Thus, any genuine effect of radiation exposure upon the risk of circulatory disease must be operating against this markedly reduced background level of major risk factors for cardiovascular disease, and clearly there are variations in the presence of these factors within the workforce. A further indication of these variations is provided by an analysis of various subgroups within the BNFL workforce. For example, ERR/Gy values for male BNFL "white collar" workers range from 1.38 (90% CI: -0.05, 3.27) for those monitored only for exposure to external sources of radiation, to -0.29 (90% CI: <-0.66, 0.21) for those also monitored for radioactive materials taken into the body (although the ERR/Gy is in terms of the external radiation dose only, and does not account for any additional dose received from internal emitters), and there is significant heterogeneity ($p = 0.016$) in the ERR/Gy values for male workers divided into "white collar", "blue collar", external exposure only, and external plus internal exposure subgroups [14]. This suggests that non-radiation effects are playing an important role in generating the patterns of circulatory disease risks within the BNFL workforce, and reliable conclusions cannot be reached until the distributions of these background risk factors are properly understood. Unfortunately, while external radiation dose is comparatively easy to obtain for BNFL workers, this is generally not the case for levels of major circulatory disease risk factors, such as smoking, so that firm inferences are difficult to make until data addressing these factors is extracted from occupational records, if indeed this is possible.

The situation is better for the Mayak workforce, where information on smoking, alcohol consumption, BMI and hypertension is currently available for the analyses [11]. The ERR/Gy values for the Mayak workforce shown in Table I are adjusted for these background risk factors, although these adjustments were reported to have had little effect upon the ERR/Gy values [11]. Nonetheless, the differences between the ERR/Gy values for incidence of, and mortality from, ischemic heart disease and cerebrovascular disease shown in Table 1 – the incidence values are notably higher than the mortality values, especially for cerebrovascular disease – do require a satisfactory explanation before the risks associated with external radiation exposure in the Mayak workforce can be appropriately interpreted.

CONCLUSIONS

Epidemiological studies of radiation workers form one piece of evidence on the potential risk of cardiovascular disease produced by low-level exposure to radiation. At present, however, the findings of occupational studies cannot be reliably interpreted because of the lack of a proper understanding of the influence of important background risk factors for cardiovascular disease on the results. The combination of occupational studies with those of medical and environmental exposures, and particularly of the Japanese atomic-bomb survivors exposed to low doses, should assist in an appropriate assessment of epidemiological findings, although the pattern of risks between categories of circulatory disease in the Japanese survivors is a complex one that is not easily explained [6]. This current state of the epidemiological evidence has led some, for example Akiba [20], to conclude that the presently available epidemiological findings “do not constitute convincing evidence for an excess risk of circulatory disease in relation to low-level radiation exposure” [20].

Fundamentally, interpretation is impeded by the absence of a broadly accepted radiobiological mechanism that would make a direct cause-and-effect explanation of the epidemiological associations, such as they are, plausible. Only further epidemiological and experimental research will improve the situation. Meanwhile, Little et al. [9] concluded that “if associations between low-level exposure to radiation and circulatory diseases reflect an underlying causal relationship that is linear at low doses, then the overall excess risk of mortality after exposure to low doses or low dose-rates of radiation may be about twice that currently assumed based on estimated risks of mortality due to radiation-induced cancers alone.” However, Little et al. [9] also emphasized the “need to conduct more detailed epidemiological studies that are capable of addressing potential confounding and misclassifying factors and possible selection bias that could influence these results, and in particular the need for a better understanding of biological mechanisms that might be responsible for the association.”

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APPROACHES FOR ESTIMATING PROBABILITY OF CAUSATION FOR COMPENSATION PURPOSES

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Abstract

Occupational exposure to ionizing radiation may in rare cases result in adverse health effects for workers, most notably cancer. As it is not possible to identify if a cancer was indeed caused by occupational radiation exposure, epidemiological approaches are used to estimate the probability of causation, making inferences from larger groups with such exposures to the individual case. A 2010 publication jointly prepared by IAEA, ILO and WHO provides an overview on risk attribution and examples for the application of this framework in attribution –based compensation programmes. The paper outlines the general principles of attribution and current concepts as well as available software to estimate probability of causation.

INTRODUCTION

Workers may be exposed to ionizing radiation at their workplace. Ionizing radiation is an established cancerogen and known to produce other health effects, notably on the cardiovascular system. Thus, the question may arise whether an occupational exposure to radiation is causative for subsequent ill health, notably cancer, among exposed workers. While questions of cause and effect are difficult to answer with certainty in the field of health and its potential determinants, several scientifically accepted approaches exist to assess whether a distinct exposure can be considered a cause of a health outcome. In the case of ionizing radiation, there is no doubt that exposures raise the probability of falling ill from cancer among exposed individuals or groups, although the exact shape of the dose-response curve remains unclear, particularly in the low-dose range. However, it remains impossible to date to confirm that a specific cancer in an individual is caused by this individuals' ionizing radiation exposure. Thus, approaches are needed to describe the likelihood that an individual case is actually due to prior radiation exposure, and to use the insight thus obtained to develop fair mechanisms of financial or other compensation for the affected individual and his or her family. These approaches are usually based on the epidemiological concept of probability of causation, which is related, but not the same as the concept of attributable fraction. The general idea is to quantify the contribution of an exposure to the total incidence (or mortality) due to exposure and to use this knowledge for a science-based judgement on the question of compensation.

The 2002 International Conference on Occupational Radiation Protection led, inter alia, to a recommendation for the international organizations to produce guidance on the formulation and application of probability of causation schemes for the compensation of workers for radiation-induced occupational diseases. This was to some extent achieved with a 2010 publication co-sponsored by ILO, IAEA and WHO that focused on approaches on how to attribute detrimental health effects to occupational radiation exposure [1]. What are these approaches, and what are the theories behind them?

TERMINOLOGY

Levin (1953) introduced the term "attributable risk" in the context of quantifying the impact of smoking on lung cancer occurrence. There are numerous synonyms or related terms, as for example outlined in Benichou and Malta [2]. The attributable risk generally measures the proportion of the disease risk among exposed persons (e.g. workers occupationally exposed to ionizing radiation) that can be attributed to the exposure, e.g. ionizing radiation. Probability of causation is a somewhat more general term denoting the probability that an exposure played a role in the disease occurrence. In the joint publication [1], the term assigned share (AS) was used alongside with probability of causation (PC) to denote the proportion of cancer cases that can be ascribed to the exposure in a notionally large population of workers with the same characteristics as the specific case under study. It follows that probability of causation refers to a given case, and the specific characteristics regarding timing and exposure dose as well as issues such as sex, age and further cofactors of this case are used to statistically estimate the probability of causation in a theoretical population of cases, such as the one under consideration. This population estimate is then re-applied to the individual case. A PC above 50% is often considered to imply that a cancer was more likely than not caused by the exposure of interest, such as ionizing radiation. Criticism of this reasoning has been formulated by several authors [3].

ESTIMATION APPROACHES FOR CANCER RISK ESTIMATION

Epidemiological information about the extent of risk associated with radiation exposure, particularly the risk per unit dose, is essential to calculate a numerical value of the probability of causation. In simple terms, an unbiased estimate of the relative risk or the excess relative risk is used, often derived from large epidemiological studies such as the Life Span Study (LSS) and available for specific cancers and the specific exposure situation and cumulative dose level relevant for the case of interest. An attributable risk measure is then calculated using the formula,

$$\text{AS} = \frac{RR-1}{RR} \quad \text{(for ERR: } \frac{ERR}{ERR+1}\text{)}$$

More specifically, and taking into account the age attained (a) and the model-based ERR (or another measure of excess risk), the value of interest is calculated as:

$$\text{AS} = \frac{ERR\,(a)}{ERR\,(a)+1}$$

This value is considered to represent the proportion of the cancer risk that can be assigned to the exposure, with values between 0 and 100%. However, as noted above, the concept of probability of causation is somewhat different from the attributable risk concept, which may result in understating the probability of causation. Another important consideration is related to the fact the commonly used risk coefficients are based on study results from the LSS, with its specific exposures, a particular population etc. Thus, the application of knowledge gained from one exposed group to another exposed group, is prone to uncertainty.

COMPLEX APPROACHES

More complex approaches, implemented in software as outlined below, incorporate the modelling of specific risk estimates for different cancer types; in both sexes and taking into account numerous population and exposure details. Errors in dosimetry are considered as well as different radiation qualities, the transfer from the Japanese to other populations, and, at least partially, other cancer risk factors. A major issue in all estimations is uncertainty, for which there are numerous sources [4]. For example, the dose information may be imprecise, the shape of the dose-response curve used for the calculations may be uncertain, and the specific aspects of the transfer of risks from one population to the other may not be clear. Issues of uncertainty are nowadays also included in the models that are used to estimate the probability of causation. However, an approach that incorporates uncertainty does not necessarily yield a "certain" estimate, but rather is expected to be a scientifically more accurate expression of a situation for which imperfect knowledge exists.

CALCULATION SOFTWARE

The era of two-dimensional radio-epidemiological tables has been surpassed by specialized software programmes to calculate probability of causation, such as the Interactive Radio-epidemiological Program IREP [5]. This program requires case-specific data entry such as year of birth, year of diagnosis, cancer type and dose information as input and calculates a point estimate for the probability of causation along with uncertainty limits. For certain cancers, additional risk-relevant information can be entered, such as for ethnicity, smoking status etc. IREP is designed for use in occupational illness claims among energy employees. Several other programmes or codes to support the calculation of probability of causation in questions of radiation-related cancer exist. In Germany, the ProZES programme is currently under development by the HelmholtzZentrum in Munich. ProZES will incorporate German baseline rates and use slightly different risk models as compared to IREP.

A NOTE ON DETERMINISTIC HEALTH EFFECTS

Deterministic effects of ionizing radiation effects are commonly thought to occur beyond a dose threshold: below the threshold, no effect is seen, beyond the threshold, all exposed persons will develop the health consequence, for example skin burns from ionizing radiation. The dose above the threshold influences the severity of the health effect. In terms of probability of causation, the effect can be considered 100% caused by the exposure. However, this is what the system of occupational radiation protection is all about: deterministic health effects must be entirely prevented, and the probability of stochastic effects must be reduced as low as reasonably achievable.

CONCLUSIONS

The concept of probability of causation rests on an epidemiological and statistical basis. In the field of occupational radiation exposure, this approach is used to assess the likelihood that an individual cancer case is caused by ionizing radiation exposures. Based on this assessment, compensation claims can be adjudicated. Both for the actual calculation as well as for the interpretation of the data, uncertainty from various sources needs to be taken into account. Several software programmes support the estimation of probability of causation for claims cases.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 3

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INTRODUCTION

This report briefly summarizes the two contributed papers submitted to the Session-3 of the Second International Conference on Occupational Radiation Protection, Vienna.

SUMMARY

The two contributed papers were submitted to this session:

- Paper 1 Occupational Radiation Exposure, DNA Damage and Genetic Polymorphisms in DNA Repair Genes (F. Zakeri et al); and
- Paper 2 Endothelial Progenitor Cells in Peripheral Blood of Cardiac Catheterization Personnel (S. Korraa et al.).

These papers have two common features. First, in both papers the study population involves health workers exposed to ionizing radiation during fluoroscopy procedures. Second, both papers selected as one of their end points the frequency of micronucleus (MN) in peripheral lymphocytes by using the cytokinesis-block micronucleus assay. The cytokinesis-block MN assay in peripheral blood lymphocytes is a validated technique of biological dosimetry that has been used for estimating the dose after accidental exposures to radiation. It has also been used to evaluate levels of DNA damage in workers occupationally exposed to radiation. It has to be noted that, in addition to radiation, other genotoxic agents (e.g. tobacco) can increase the MN frequency and that the baseline MN frequency depends strongly on age and gender.

The objective of the first paper is to determine the relationship between genetic polymorphisms in genes coding DNA repair enzymes and the levels of DNA damage in interventional cardiology staff. The characteristics of their study population are summarized in Table 1.

TABLE 1. SUMMARY CHARACTERISTICS OF THE STUDY POPULATION.

Characteristic	Exposed Group[(a)]	Control Group
Males	59	38
Females	31	22
Total	90	60
Mean age (years +/- SD)	41.5 +/- 7.6	41.4 +/- 9.1
Mean last year exposure	3.5 +/- 2.7 mSv	-
Mean last 5 years exposure	11.2 +/- 10.5 mSv	-
Mean years of employment	9.5 +/- 6.7	-

[(a)] Interventional cardiologists, technicians and nurses

Two types of end points were considered in peripheral blood lymphocytes. As mentioned above, they evaluated the frequency of micronucleus by cytokinesis-block micronucleus test in binucleated cells. In addition to that they evaluated single nucleotide polymorphisms (SNPs) by polymerase chain reaction combined with restriction fragment length polymorphism (PCR-RFLP genotyping assay) in genes coding DNA repair enzymes: XRCC1, OGG1, APE1, XRCC3, and XPG.

The results can be summarized by saying that the MN frequency was significantly higher in:

- Exposed group vs. control group;
- Within exposed group >3mSv/y vs. ≤3mSv/y;
- Within exposed group >10 years vs. ≤ 10 years of exposure;
- Exposed group carrying SNPS in the genes XRCC3 and XPG; and
- Control group carrying SNPs in the gene OGG1.

Authors concluded that the occupational exposure to ionizing radiation in interventional cardiologists, technicians and nurses is associated to increase in DNA damage expressed as a higher MN frequency. The DNA damage was higher in individuals carrying genetic polymorphisms in DNA repair enzymes (SNPs), suggesting that this might represent a particularly vulnerable population (mutagenic and cancer risk). The relationship between MN and SNPs in genes involved in DNA repair may contribute to evaluate susceptibility to ionizing radiation in individuals occupationally exposed.

The second paper evaluated the level of circulating endothelial progenitor cells and its correlation with DNA damage in staff exposed during fluoroscopy cardiac procedures. The characteristic of their study population is summarized in Table 2.

TABLE 2: SUMMARY OF THE CHARACTERISTICS OF THE STUDY POPULATION

Characteristic	Exposed Group[(a)]	Control Group
N Total	70	40
Smokers	34	-
Non-smokers	46	40
Mean age (years +/- SD)	42.8 +/- 5.2	42 +/- 4.8
Annual dose (range)	2.16 – 8.44 mSv/year	-

[(a)] staff involved in fluoroscopy-guided cardiac catheterization in 3 hospitals in Cairo, Egypt

Three types of biological end points were considered in peripheral blood samples. As mentioned above they evaluated the frequency of micronucleus in peripheral blood lymphocytes by cytokinesis-block micronucleus test in binucleated cells. In addition to that they evaluated the number of Endothelial Progenitor Cells (EPCs) in peripheral blood (PB) by flow cytometry with monoclonal antibodies for CD133, CD34 and kinase domain receptors

(KDR) and the plasma levels of stromal growth factor (SDF-1) using ELISA assay. The staff involved in fluoroscopy-guided cardiac catheterization (CC) presented:

- Significantly higher micronucleus (MN) frequency;
- Significantly higher number of Endothelial Progenitor Cells (EPCs) in peripheral blood;
- Significantly higher plasma levels of stromal growth factor (SDF-1); and
- Smoker CC staff exhibited higher MN frequency and SDF-1 and lower levels of EPCs than non-smokers.

The authors concluded that staff involved in fluoroscopy-guided cardiac catheterization present and increased MN frequency, which is higher in smokers vs. non-smokers. Circulating EPCs numbers and SDF-1 plasma levels, which are markers of endothelial activation/damage, are significantly increased in the radiation-exposed group. The dual effect of IR and smoking (i.e. additive effect on inducing SDF-1 expression as other DNA damaging agents, with an opposite effect on the number of EPCs in peripheral blood) is interpreted as a regenerative process decreased by smoking. Further studies are needed to elucidate the role of EPCs as a potential marker of radiation exposure.

CHAIRS' SUMMARY OF TOPICAL SESSION 3

In the session an update of knowledge regarding the health risks associated with occupational exposure to ionizing radiation was presented. After a general overview, the issue of effects in the eye lens, and that of the risk of cardiovascular disease were discussed in specific presentations, as were developments in the concepts of probability of causation, and of new computerized methods for its calculation.

The points discussed were relevant not only for radiation protection professionals, but also for occupational health professionals not knowledgeable in radiation protection. In fact, for the latter professional group increasing the level of knowledge and awareness of the risk(s) associated with ionizing radiation are highly desirable.

In the keynote lecture, Prof. Dr Müller, of the Institut für Medizinische Strahlenbiologie, Universitätsklinikum Essen, Germany, discussed the differences between deterministic and stochastic effects. The former, covered also by the International Commission on Radiological Protection (ICRP) term "tissue reactions", are related to death of multiple cells, and manifestly occur after exceeding a dose threshold (in most cases in excess of one gray or more) and their severity are-dose related. In contrast, stochastic effects, initiated by modifications (in particular of the genome) compatible with survival of the cells, can ostensibly occur without threshold, and affect the incidence of disease in an exposed population that increases with increasing dose (the so-called LNT concept, Linear Non-Threshold).

The lecture explained that biological arguments existed for models other than LNT, especially at low and very low dose; however, these arguments could not be confirmed, so assumptions had to be made on the model to use for protection purposes.

Currently, it was not clear whether cataracts and circulatory diseases were of a deterministic or a stochastic nature or something else. The same issue applied to some radiation effects during pregnancy such as to the induction of malformations during the early pre-implantation period of the embryo that had been observed in some mouse strains, or reduction in IQ.

The presentation discussed attribution of health effects to exposure: on an individual basis it is challenging to decide whether a specific health effect can be attributed to ionizing radiation exposure. Attribution is possible for deterministic effects after high acute doses, but a stochastic effect in an individual cannot be unequivocally attributed to radiation exposure, because: (a) radiation exposure is not the only possible cause, and (b) there are no available specific biomarkers evidencing that radiation was responsible for the observed health effect.

The presentation also discussed inference of risk in the low and very low dose range, for which the prediction of future stochastic health effects in a strict scientific sense is very uncertain. Generally, it does not make sense to calculate numbers of cases of death based on the multiplication of low doses or, in particular, very low doses and the number of individuals affected. An exception to this may be when comparing options in certain situations, but it is important to recognize the uncertainties and that the numbers of effects are notional in nature.

Prof. Norman J. Kleiman of the Columbia University presented the "Scientific and epidemiological background for radiation risk to the lens of the eye". The lens is one of most radiosensitive organs of the body. The target is a small subset of lens epithelial cells and, according to the results of experimental data in animals; the pathogenesis may be related to genotoxic damage.

Increased incidence of cataracts was reported in various epidemiological studies, on cohorts such as the atomic bombing survivors, astronauts, clean-up workers after the Chernobyl accident, and radiological technologists and other medical personnel such as those involved in interventional cardiology. Based on the results of the available studies, ICRP had reduced the eye lens limit from 150 mSv to 20 mSv in a year.

The rate of progression of radiation-associated lens changes seems slow. While treatment is surgical removal of the cataract, potential visual disability and morbidity resulting from the radiation cataract and/or its treatment may be underappreciated.

To date it is still not clear whether radiation-associated cataracts related to exposure at low doses are stochastic or deterministic in nature. Establishing an accurate dose threshold, if any, for radiation cataractogenesis is considered important for risk assessment and exposure guidelines.

The speaker concluded that additional studies, for example in other cohorts of interventional physicians and associated medical workers, may help to further refine occupational exposure of the eye lens and appropriate risk guidelines.

Prof. Richard Wakeford of the University of Manchester (UK) presented "Evidence of cardiovascular disease risk in the workplace. Increased risk of cardiovascular diseases, such as heart attack and stroke, is well established following high acute doses of ionizing radiation, and the underlying radiobiological mechanism known. However, some epidemiological studies in nuclear industry workers, Chernobyl emergency workers, and uranium miners have suggested a raised risk of circulatory disease at lower levels of exposure to radiation, implying that radiobiological mechanisms associated with low/moderate acute doses or low/moderate dose-rates might be increasing the risk of cardiovascular disease. However, the pattern of elevated excess relative risks associated with exposure to external sources of gamma radiation in the workplace needs to be interpreted cautiously. The results of some studies indicate that major background risk factors for circulatory disease, such as cigarette smoking, stress, alcohol consumption and body mass index (BMI), need to be taken more adequately into account. Data of other studies suggest the occurrence of the "healthy worker effect" and an uneven distribution of major background risk factors for cardiovascular disease. The speaker concluded that, currently, the findings of occupational studies cannot be reliably interpreted because of the lack of a proper understanding of the influence of important background risk factors, and of a broadly accepted radiobiological mechanism. Thus, the findings currently available do not give adequately convincing evidence for any excess risk of circulatory disease in relation to low-level radiation exposure.

Currently the ICRP does not include radiation-induced risks of non-cancer somatic diseases, such as circulatory diseases in the exposed individual, at low-level exposures in the framework of radiological protection.

The last speaker, Prof. Hajo Zeeb of the Leibniz Institute for Prevention Research and Epidemiology, presented "Approaches for estimating probability of causation for compensation purposes". He recalled that even if it is accepted that an occupational exposure to ionizing radiation may result in various adverse health effects, there is a problem to answer the question as to "how likely is it that ionizing radiation contributed to the development of this effect?" Manifest disease (say: a cancer) cannot be unequivocally attributed to a specific cause, as ionizing radiation.

The approaches applied to describe the likelihood that an individual case was actually caused by prior radiation exposure are based on epidemiological and statistical approaches, drawing inferences from large exposed populations to individual cases, using the concept of probability of causation.

Thus, knowledge from epidemiology is used to make a science-based judgement on the question of causality. But when transferring results from a population to a specific case, uncertainty from various sources needs to be taken into account, e.g., relating to the case: uncertain dosimetry, disease information, and information on other factors relevant to risk; and relating to the models used: the shape of the dose–response curve, use of a dose and dose rate reduction factor (DDREF), biological effectiveness, transport from one population to another, and so on. The speaker noted that, in any case, the criteria for deciding on compensation are legally based, not pure science. New software tools are becoming available to readily assess probability of causation using standard models based on knowledge about exposure, possibly including additional risk-relevant information such as ethnicity, smoking habits and so on.

The speaker concluded that the concept of probability of causation rested on an epidemiological and statistical basis. Both for the actual calculation as well as for the interpretation of the data, uncertainty from various sources needs to be properly taken into account when estimating probability of causation for claims cases: new software programmes may be helpful in this estimation.

TOPICAL SESSION 4:

DOSE RECORD MANAGEMENT OF OCCUPATIONAL RADIATION EXPOSURES

Chairpersons: S. Soloman, Australia and F. A. Ollite, Mauritius

ISSUES IN THE MANAGEMENT OF SPANISH NATIONAL DOSE REGISTRY

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Abstract

In 1985 the Nuclear Safety Council decided to create the National Dose Registry (BDN), in order to ensure the availability of individual records at any time. The main objectives of this data base are to provide a safe and secure long-term dose record keeping, to facilitate a prompt identification of any exceeding dose limit, to provide data to carry out studies on exposure trends and to provide support to carry out epidemiological studies involving monitored workers. Monthly, Dosimetry Services (DS) must send electronically, through the CSN's website (www.csn.es), according to a format telematically prescribed by CSN. Spanish regulations on personal data protection (Law 15/1999), regards dose records as health-related information, thus, maximum level of confidentiality is maintained. There are different levels of access to the database, which helps to ensure the traceability of all the accesses and changes made in the database, as well as securing the data. The National Data Protection Agency from Spain audits the BDN every two years. The classification model of the data included in the BDN opens broad possibilities for a sophisticated statistical analysis ("ESTADISTICAS"), whereby CSN can identify exposure trends and different studies can be carried out.

INTRODUCTION

The Nuclear Safety Council (CSN) was set up in 1980 as an entity under the Common Law, independent from the General State Administration, with a legal standing and equity of its own and independent from those of the State, and as the sole competent authority in matters related to nuclear safety and radiological protection. The CSN provides with annual information to the Spanish Parliament, sending a report which covers in great detail the activities carried out during the year. The president of the CSN holds a yearly hearing at the Spanish Parliament to present this report.

LEGAL FRAMEWORK

The dosimetry surveillance of workers in Spain, exposed to ionizing radiations is regulated by the provisions of Royal Decree 783/2001, which approves the Regulation on the Protection of Health against Ionizing Radiations. The most important statements that have to be considered in the current context are the following:

- Individual dosimetry, be it external or internal, shall be carried out by the Personal Dosimetry Services expressly authorized to do so by the Nuclear Safety Council. Table 1 gives the categorization of workers used.
- It shall be mandatory to record all the doses received during the working life of the exposed workers in an individual dosimetry record, that shall be kept, duly updated, and which shall at all times be at the worker's disposal.

To these effects, it shall also be obligatory to record, conserve and maintain the following documents at the worker's disposal:

- In case of accidental and emergency exposures, the reports regarding the circumstances and the measures adopted;
- The results of the working area monitoring that may have been used to estimate the individual doses.

TABLE 1: JOB CHARACTERISATION OF WORKERS

MAIN WORK SECTOR	SPECIFIC WORK FACILITY	TYPE OF WORK
A) Medicine	Diagnostic radiology Nuclear medicine Radiotherapy Dentistry Radiation protection services Other	Doctors Health assistant (nurse) X-ray assistant Assistant Radiation protection workers Other
B) General Industry	Radiography Gammagraphy Processing control Gauges for measurements of density, positions and thickness Well-logging (the oil and gas industry) Production of radioactive materials	Supervisor Operator Assistant Transport worker Other Other
C) Research and Teaching	X-ray facilities Sealed sources Unsealed sources Electron accelerator units Neutron sources Mixed	Supervisor Operator Assistant Academic research and teaching personal Other
D) Nuclear Power Plants	Nuclear Power Plants	Normal operations Refueling outage Nuclear reactor maintenance Shutdowns Decommissioning
E) Fuel Cycle	Mining Milling Nuclear fuel fabrication Radioactive waste management	Normal operations Decommissioning
F) Nuclear Safety Council		Regulatory control
G) Transport	Transport	Waste transport Nuclear fuel cycle transport Radioactive material transport

The following shall be registered in the corresponding dosimetry record for the workers within Category A: the monthly doses, the accumulated doses in every official year, and the accumulated doses in every period of five consecutive official years. In the case of workers within Category B, the annual doses, determined or estimated, shall be included.

Those workers who are exposed to more than one working activity or facility are obliged to inform about this circumstance the Head of the Radiation Protection Service or Radiation Protection Technical Unit, or in their absence, the Supervisor or person who has been entrusted with the duty of the radiation protection in each institution in which they work. This is to ensure that in each institution the dosimetry record is maintained and updated. The worker must communicate each involvement associated with the dosimetry results. In case of a change of the employer, the worker must provide a certified copy of the corresponding dosimetry record to the management of the new destination.

The dosimetry record of the exposed workers, the documents related to the dose evaluation, circumstances and measures taken in the case of emergency exposure and measures taken by the monitoring teams must be recorded by the management of the facility. This requirement applies from the day the worker has been qualified as radiation worker until the worker has reached (or would reach) 75 years. The minimum recording period is thirty years. If worker resigned from the position held or the institution terminated the operations, the management of the institution shall provide the worker with a certified copy of the dosimetry record.

THE NATIONAL DOSE REGISTRY (BDN)

The CSN decided in 1985, to create the National Dose Registry (BDN), in order to ensure the availability of individual records at any time.

The main objectives of the BDN are:

a) To provide a safe and secure long-term dose record keeping, redundant to that required to the licensee;
b) To facilitate a prompt identification of any exceeding dose limit.
c) To provide data to carry out studies on exposure trends, in order to identify potential areas of ALARA concern.
d) To provide support to carry out epidemiological studies involving monitored workers.

— Information included in each data record

The information included in each data record consists of:

- Personal data: The unique personal identification as given in the National Identification Document Number, full name, first name, maiden name, date of birth, sex, type of work etc.
- Worker's personal data and job characterization: BDN includes information about the work sector, the specific area within that sector, and, moreover, the job description, as represented in the table included at the end of this report.
- Dose Data: The information recorded consists of: monitoring period, external whole body doses (in terms of Hp (10) and Hp (0.07)), and "other doses" (dose from internal exposure, extremity dose, abdominal dose). The recording level for external dose rate is 0.10 mSv per month; in the case of internal exposure the recording and investigation

level is 1 mSv per year. The Dosimetry Service (DS) shall assign a notional dose[1] to the monitored worker in the event the dosimetry information is lost or the routine personal dosimeter is not returned for processing after more than three months.

— Dose data submission by dosimetry services

The content of the reported information and the format of the data were prescribed by CSN when the BDN was established. Every month, dosimetry services (DS) must send telematically the dose records by digital signature to BDN, through the CSN's website. Every DS had to be authorized by the CSN before transferring the data to the BDN and a password to access to the system must be provided.

A report is generated as a result of the validation process, and the user (DS) may obtain warning message if problems in the uploading were detected.

— Software and structure

The BDN runs the SOLARIS operating system and uses oracle data base manager. A specific module in the BDN is used for uploading and validating the data transferred by the BDN, managed by one operator fully dedicated to this mission. Associated to this module, there is an e-mail account (bdn@csn.es) whereby the operator is notified about the uploading process (evolution, errors, incidences, etc.).

— Data analysis after the upload process

Once the monthly data have been uploaded and validated by the operator, the BDN automatically proceeds to the assessment of the following three indicators:

- Accumulated dose in the current year / worker;
- Accumulated dose in the last five years / worker; and
- Monitored workers that have exceeded any of the dose limits fixed in the normative.

— Overexposure management module

There is a specific module in the BDN devoted to the management of "overexposure cases". It shows a list of alerts and warnings to the operator, in which all cases of doses exceeding the limits are recorded.

— Data protection and confidentiality

According to Spanish regulations on personal data protection (law 15/1999), dose records are regarded as health-related infomation, thus, maximum level of confidentiality is maintained. However, there are no limitations for the use of the data from BDN in anonymous form for research purposes. The National data protection agency audits the BDN data every two years.

Access to the BDN is granted only to the dosimetry department staff of the CSN via digital certificate of their identity. There are different levels of access to the database, which vary from

[1] 2 mSv/month for $H_p(10)$, and 40 mSv/month for $H_p(0,07)$.

writing and reading permission (to just reading permission. This hierarchy helps to ensure the traceability of all accesses, enquiries and changes made in the database. Each level of access is linked to the user's id.

According to the regulations on personal data protection, the workers must have access to their personal data included in the database. This access is provided through the CSN web page and requires the electronic certificate of the worker's identity. The system displays a "note" to the worker, clarifying some issues about the information contained in the BDN, especially about the fact that the data contained in the BDN may not exactly correspond to those included in the worker's individual dosimetry record.

— Statistics and data analysis

The classification model of the data included in the BDN opens broad possibilities for a sophisticated statistical analysis ("ESTADISTICAS"), whereby CSN can identify exposure trends and different studies can be carried out. Different parameters can be used for data analyses — time period, dose intervals, dose type, and work characteristics.

— Examples of the BDN applications

Every year the CSN provides the Spanish Parliament with an annual information about occupational exposure of workers. Moreover, the annual reports contain analysis of the dose distributions in different work sectors, comparison with international recommendations, comparison with similar data from other European countries, USA and CANADA, analysis of the trends in the development of the collective dose patterns.

The dose information and the statistical analysis prepared by the BDN are useful tools for effective operational protection of the occupationally exposed workers. In fact, it represents a useful tool for many of the functions that the Nuclear Safety Council has been entrusted with, such as the inspection to radioactive facilities (data source: number of monitored workers, accumulated doses in the facility, or by the workers, etc.), or the management of dose limits exceeding cases, amongst others. Finally, it also brings help as a data source for reports required by the Court in case of worker's claims.

— Practical issues

An accurate job characterization is not always feasible for the Dosimetry Service submitter of the data. Management of such a big amount of computational data, implies a high incidence of mistakes that need to be effectively dealt with.

UNSCEAR REQUIREMENTS FOR OCCUPATIONAL DOSE DATA

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Abstract

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) continuously evaluates the worldwide levels of occupational radiation exposure for two broad categories of sources: natural sources of radiation and man-made sources of radiation. The UNSCEAR evaluation is based on data from the UNSCEAR Global Survey of Occupational Radiation Exposures conducted by formal request to all 192 Member States of the United Nations, supplemented with data from literature. The UNSCEAR evaluations need to provide information relevant for policy and decisions regarding the use and management of radiation. The UNSCEAR questionnaire is designed in order to obtain the basic data to evaluate the level of occupational exposure in each sector and sub-sector of work. Specific additional information is requested for each sector or subsector and category of worker; as well as information to evaluate the reliability of the data. The UNSCEAR questionnaire is in good agreement with currently updated national databases. Since these databases for occupational exposure are the main source of information for UNSCEAR, they need to be regularly updated in order to reflect any change on the level of occupational radiation exposure when new technological developments and modifications to work practices occur.

INTRODUCTION

The term occupational radiation exposure is often taken to mean those exposures received at work, which can reasonably be regarded as the responsibility of the operating management [1-3]. Such exposures are normally subject to regulatory control, with the requirements for practices as defined by the IAEA Basic Safety Standard [1]. The exposures are usually determined by individual monitoring, and the doses assessed and recorded for radiological protection purposes. The International Atomic Energy Agency, in its publications [1-5] has provided guidelines on how monitoring data and results should be reported. Although guidelines for dose recording are available, the procedures for the recording and inclusion of occupational exposures differ from practice to practice and country to country.

UNSCEAR has evaluated the occupational exposure to various sources of radiation since 1975. In the early years the main focus was on practices related to the nuclear fuel cycle. However, new technological developments and modifications to work practices are occurring constantly, particularly in the medical and industrial sectors. More recently, exposure to natural sources of radiation is receiving greater attention from regulatory bodies where large numbers of workers are potentially exposed to doses that may even reach legal dose limits. With the constant development of new technologies, new groups of workers exposed to high doses of radiation may emerge as has happened with interventional procedures in medicine.

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) has continuously evaluated the levels of occupational radiation exposure for two broad categories of sources: (1) natural sources of radiation and (2) man-made sources of radiation. The evaluation of the worldwide occupational exposure levels is based on data from the UNSCEAR

Global Survey of Occupational Radiation Exposures, conducted by formal request to all 192 Member States of the United Nations; supplemented with data from literature. The UNSCEAR evaluations need to provide information relevant for policy and decisions regarding the use and management of radiation. This includes:

(a) To provide a reliable and comprehensive estimate of worldwide dose distributions and trends so that they may be placed in context;
(b) To provide insight into the main sources of exposure, the most significant exposure situations and the main factors influencing dose distributions and trends, reflecting as appropriate high-level concerns of the United Nations (such as those related to environment, security, human rights and gender issues);
(c) To facilitate evaluation of the impact of new techniques or technologies, of regulatory changes and of risk management programmes;
(d) To identify emerging issues and opportunities for improvement that may warrant more attention and scrutiny;
(e) To provide authoritative information that can be used for communicating, formulating or underpinning policy and decisions, and for investigative work; and
(f) To provide insight into the reliability of the evaluations and identify areas for future research.

For the UNSCEAR 2008 Report [6] a new questionnaire was developed requesting more detailed information compared to the previous ones. However, the structure of some national databases for occupational exposure did not provide the detailed information requested in the questionnaire. Another problem was that the worker taxonomies were often confusing due to inconsistent classification between activity sectors or subsectors and occupational categories. For example, in the medical sector one worker could have been characterized alternatively as belonging to an interventional radiology or conventional radiology department; or as being a nurse or a radiographer or an anaesthetist. These two types of information were classified under the same heading. There were even worse situations, where workers in the medical sector were all pooled together, without even discriminating by the main occupational categories for the medical sector.

DATA NEEDED FOR UNSCEAR EVALUATION

The UNSCEAR questionnaire is designed to obtain the basic data to evaluate the level of occupational exposure in each sector and sub-sector of work; which are the average effective dose and the number of workers for different dose intervals in mSv (below the minimum detectable level or MDL: MDL<1; >1–5; >5–10; >10–15; >15–20; >20–30; >30–50; >50) as shown in Table 1. Specific additional information is requested for each sector or subsector and category of worker. Additional information is also requested to evaluate the reliability of the data about the value of the minimum detectable limit, value of the recording level, and information about accreditation or authorization of the individual monitoring services for internal and external dosimetry.

The data is requested for each specific sector, subsector and if needed for each category of work. The sectors and subsectors for exposure to natural sources of radiation are:

- Civil aviation;
- Extractive industries:
    - Civil aviation;

- Coal mining, which is broken in underground and open pit mining;
- Other mineral mining, which is broken in underground and open pit mining;
- Oil and natural gas industries;
- Processing of mineral ores;
- Workplaces other than mines with substantial exposure to radon.

The source of exposure for the workers from extractive and processing industries can be inhalation of radionuclides and/or inhalation of radon gas as well as exposure to external sources of radiation. The contribution of each one of these sources of exposure on the effective dose needs to be evaluated. However, the data need to be recorded in the national database for occupational exposure.

The sectors and subsectors for exposure to man-made sources of radiation are:

Nuclear Fuel Cycle (NFC):

1. Uranium mining, which is broken in underground and open pit mining;
2. Uranium mining;
3. Uranium enrichment and conversion;
4. Fuel fabrication;
5. Reactor operation, which is broken down for employees and contractors; as well as tasks;
6. Fuel reprocessing;
7. Nuclear research;
8. Nuclear decommissioning;
9. Waste management;
10. Safety and safeguard inspections;
11. Transport within NFC; and
12. Other use in nuclear sector.

The source of exposure for the workers in most of the subsectors of NFC can be inhalation of radionuclides and/or inhalation of radon gas as well as exposure to external sources of radiation. As a result, the contribution of each one of these sources of exposure on the effective dose needs to be evaluated. For reactor operation, it is important to identify if any specific task results in higher exposure compared to the others.

Medical Sector:

1. Diagnostic radiology;
2. Interventional radiology, which is broken down in cardiology and others as well as according to job categories (medical doctors, nurses, technicians and others);
3. Dental radiology;
4. Nuclear medicine, which is broken down according to job categories (medical doctors, nurses, technicians and others);
5. Radiotherapy, which is broken down according to the technique brachytherapy and radiation beam; and
6. All other medical uses.

In the medical sector, detailed information broken down by job category (medical doctors, nurses and technicians) is required, as well as doses for lens of the eyes and for the hands.

Information about the contribution of the effective dose due to intakes of radionuclides on the total effective dose is also required.

Industrial Sector:

1. Industrial irradiation;
2. Industrial radiography, which is broken down in fix and mobile units;
3. Luminizing;
4. Radioisotopes production;
5. Well-logging;
6. Accelerator operation;
7. Transport; and
8. All other industrial uses.

In some subsectors of the industrial sector, doses for lens of the eyes and for the hands are required.

Defense Activities Sector:

1. Weapon production;
2. Nuclear ships and support activities; and
3. All other defence activities.

Information about the contribution of the effective dose due to intakes of radionuclides on the total effective dose is also required.

Miscellaneous:

1. Educational establishments;
2. Veterinary medicine;
3. Safety and inspections;
4. Waste management other than NFC;
5. Transport; and
6. Other specified occupational group

CONCLUSIONS

The UNSCEAR needs to have robust data to conduct a reliable evaluation that reflects the real picture of the occupational radiation exposure for that period of analyses. The national databases for occupational exposure are the main source of information for UNSCEAR. It is vitally important for these national databases to be updated in order to reflect any change on the level of occupational radiation exposure when new technological developments and modifications to work practices occur. The UNSCEAR questionnaire is in good agreement with national databases that are currently updated.

TABLE 1. UNSCEAR QUESTIONNAIRE PAGE RELATED TO DATA ON EFFECTIVE DOSE

Year:		Country:														
WORK CATEGORIES		ANNUAL AVERAGE EFFECTIVE DOSE FOR EACH DOSE INTERVAL (mSv)									Annual average effective dose I (mSv)	% E Radon and progeny	% E Inhalation or ingestion	% E External exposure	Dose to lens of the eyes (mGy)	Dose to hands (mGy)
		< MDL	MDL to 1	>1 to 5	>5 to 10	>10 to 15	>15 to 20	>20 to 30	>30 to 50	> 50						
+1	NATURAL SOURCES OF RADIATION															
	Different sectors															
22	NUCLEAR FUEL CYCLE															
	Different subsectors															
33	MEDICAL USES OF RADIATION															
	Different subsectors															
44	INDUSTRIAL USES OF RADIATION															
	Different subsectors															
55	MISCELLANEOUS															
	Different subsectors															
66	MILITARY ACTIVITIES															
	Different subsectors															

Additional questions		Additional questions	
Registered dose quanti—y - HE, E or HP?		Value of recording level (mSv)	mSv
Factor used to convert WLM to effective dose.	mSv	Radiation background subtracted?	
Type of dosimeter		Are the external monitoring laboratories accredited by the accreditation body or authorized by the regulatory authority?	Yes: No:
Value of MDL (Minimum Detectable Level)	mSv	Are the bioassay monitoring laboratories accredited by the accreditation body or authorized by the regulatory authority?	Yes: No:

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INDIVIDUAL MONITORING AND OCCUPATIONAL DOSE RECORD MANAGEMENT IN CHINA — HISTORY, CURRENT STATUS AND PERSPECTIVES

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Abstract

This paper reviews the history of the development of individual monitoring of radiation workers in China, describes the numbers and distribution of radiation work units and radiation workers, analyses the current status of individual monitoring of radiation workers, presents the latest data of individual monitoring services with the input China Register of Radiation Workers, and points out some problems existing in the individual monitoring of interventional radiology and nuclear medicine workers.

INTRODUCTION

The application of nuclear energy and technology began in the 1950s [1] in China. With the continuous development of science and technology, radioisotope and radiation installations have been widely used and have made important contributions in various fields of national defense and national economy. However, while we are enjoying the benefits brought about by the application of radiation, we must be alert to the risks posed by irradiation, especially damage to living organisms and pollution of the environment. In order to ensure the health and safety of radiation workers and the general public, national laws and regulations [2,3] stipulate that all workers engaged in radiation working units should be subject to individual monitoring.

Individual monitoring is a kind of routine technical service work and it is closely related to the health of radiation workers. Individual monitoring is one of the important measures of the health care of radiation workers [1] and is an important part of radiological protection. It helps us to evaluate the radiological protection of the radiation workers and improve the level of protection.

HISTORY

The nuclear industry established the individual monitoring system in the 1950s, which was the earliest sector in China. By Early 1970s, a more complete system had been established, and in 1986, a centre of individual monitoring and service was created in the nuclear industry. Individual monitoring of radiation workers was mostly conducted inside the nuclear industry system at that time. On Feb 1981, the first national meeting on individual monitoring was held, in which data of external exposure from 1959 to 1979 from nuclear reactors, reprocessing plants and research institutions were summarized and assessed preliminarily. Data were also compared with those from abroad.

China introduced the reform and opened up a new policy in 1978, focused on economic development and applications of nuclear and radiation technology. In order to meet the needs of the protection of the radiation workers, radiological protection departments of epidemic prevention stations in Beijing, Liaoning and other provinces gradually conducted individual monitoring and health examination of radiation workers in medicine and industry sectors.

In 1985, the Ministry of Health promulgated Regulations on individual monitoring for radiation workers and Methods of Individual monitoring for radiation workers. A nationwide monitoring of individual doses was gradually introduced from December 1, 1985. Before 1994, Institute of Radiation Medicine, Chinese Academy of Medical Sciences was responsible for the technical management of individual monitoring. The task has been undertaken by Industrial Hygiene Laboratory, the Ministry of Health since 1994.

CURRENT STATUS

— Law and regulation

Individual monitoring of radiation workers is required by the Law on Prevention and Treatment of Occupational Disease (adopted in 2001, put in force since May 1, 2002, and amended extensively in 2012) and more details are given in a ministry-level regulation Administration of Occupational Health for Radiation Workers (adopted on March 23, 2007, put in force since November 1, 2007).

— Radiation workers in China

At present, there are almost 60 thousand radiation units and more than 300 thousand radiation workers in China. Among them, 223 thousand radiation workers are distributed over 53 thousand radiation units in hospitals with radiation imaging and therapy facilities. 70-80% of the radiation workers work in radiology imaging, nuclear medicine and radiotherapy. Ten percent of the radiation workers are involved in industrial radiography and irradiation installations. The remaining workers are active in education, and research.

Radiation workers in the non-nuclear industrial sectors are distributed mainly in the eastern and central regions and economically developed regions in China. In the nuclear industrial sectors, most of the radiation workers are working in uranium mines. There are several thousand radiation workers in the nuclear power plants, and the number will increase in future. At present, in addition to the China Experimental Fast Reactor (CEFR) built by the China Institute of Atomic Energy (CIAE), there are 21 nuclear units in operation [4] and 27 units under construction.

The application of individual monitoring has risen steadily, currently reaching about 60% [5]. Average annual effective dose of radiation workers from 1985 to 2012 shows a significant downward trend. The use of individual monitoring in Shanghai and Beijing can reach more than 90%, and it is higher in the eastern region compared with the western regions. Monitoring of radiation workers in the nuclear power plant is the most complete.

— Individual monitoring services

There were 190 individual monitoring services in 2009, and in 2012, the number has increased to 203. CDC/institutions of prevention and treatment of occupational disease account for most of the monitoring services. Other monitoring services are distributed in nuclear industry, commercial companies, universities, environmental protection agency, etc. The distribution of the individual monitoring services is not balanced throughout the country. There are too many small scaled monitoring services in China. All of the 203 services can monitor X and gamma rays, 12 services can monitor beta surface contamination, 23 services can monitor neutron exposure, 2 services can monitor internal contamination and one service provides individual monitoring of radon.

— Individual monitoring – personal and equipment

The total number of technical personnel in individual monitoring services amounts about 500. The number of technical personnel in each individual monitoring service varies from 1 to 16 and in average there are 3.8 technical personnel in each service. An investigation [6] conducted in 2007 indicated that 87.5% of the thermoluminescent dosimetry readers from 56 individual monitoring services were domestic equipment and that 92.44% of the individual monitoring services were using thermoluminescent LiF (Mg, Cu, P) detectors. In 2012, 7% of the services that participated in the national international-comparison program failed to pass the test.

— National dose registry

Before the 1980s, individual monitoring mainly included radiation protection and monitoring in the development of nuclear industry and nuclear weapons, and there was no open reporting. With the introduction of reforms and open-door policy in 1980s, nuclear and radiation technology applications were popularized in medicine, industry and other sectors. In 1979, the Ministry of Health and other ministries re-released Management of Radioisotope Work Hygiene Protection to reaffirm the establishment of license registration and radiation incident reporting system. In 1985, individual monitoring system was formally introduced. With the popularity of computers and information technology, health and other departments had made a useful exploration for the gradual establishment of health (including radiation health) supervision.

China National Nuclear Corporation established the service centre of occupational exposure dose management in 1985, developed the DMSD, IDMS and OPIMDS data management system respectively, collected and analysed the monitoring data of 6 facilities units and several nuclear power plants, and submitted the annual assessment report. In 1998, Industrial Hygiene Laboratory, the Ministry of Health developed a Software of data processing and file management of individual monitoring for radiation workers (DPFM), trying to unify the data management of individual monitoring in the medical field. Problems existed in the software of individual monitoring information management were discussed [7-9].

In 2002, the system of health and epidemic prevention was reformed, and health supervision and technical services were separated. After successful containment of SARS in 2003, more attention was paid to collecting information for each case relevant to disease control and prevention as well as to direct reporting with using computer technology. In October 2003, the Chinese Center for Disease Control and Prevention began to run an information system of the health hazard monitoring, and reporting of individual monitoring was included.

In August 2004, an IAEA expert visited China to conduct the occupational radiation protection appraisal service (ORPAS) and pointed out that China's data reporting system of individual monitoring of radiation workers should be reconstructed. The expert strongly suggested that China should establish a national central database and to improve quality control and assurance of individual monitoring. Since 2005, funded by the IAEA, China began to establish the occupational health management system of radiation workers of Ministry of Health of China under the framework of the IAEA CPR (CPR/9/037) and finally China Register of Radiation Workers (CRRW) was officially released by the Ministry of Health in November 25, 2009. The system has authorized 212 users, including 180 individual monitoring services and 32 supervision departments in each province. From 2004, there were 2 million monitoring records which covered 330 thousand workers in 35 thousand radiation units in the central database and this situation persists up to now

Name, working unit, unique identification number, occupational exposure category, quarterly and annual effective doses are uploaded by each monitoring service and maintained in the register. Backup system including optical disks and hard disks were used to safely store the dose records.

ISSUES AND CONCLUSIONS

— Long wearing cycle of dosimeters

The wearing cycle of the dosimeters is maximum 3 months in most areas of China, while the regulation [3] requires that the wearing cycle of the dosimeters should be 1 month in general.

— Weak ability of the monitoring service

Generally, the number of the monitoring services in the developed countries is small, but they usually have a big size and heavy workload [10]. However, most of the monitoring services in China are small and the workload is too small. Most services cannot carry out comprehensive individual monitoring [6].

At present, the vast majority of monitoring services can only provide monitoring of external gamma and X-ray radiation doses [11]. Individual monitoring of beta, and doses to hands, as well as internal contamination are not carried out sufficiently. In terms of individual monitoring of external radiation, problems such as comprehensive accreditation of personal dosimeter, strengthening the routine quality control and assurance and timely uploading the monitoring data, as well development of eye and extremity dosimeters are to be solved.

— Quality and accuracy of the data

In the actual monitoring work, monitoring of the natural background radiation is not uniform [6]. When calculating the dose, some services included the background radiation, and some did not. In China, about 95% of radiation workers are receiving an annual effective dose of less than 5mSv, while in average about 93% of radiation workers are receiving an annual effective dose of less than 1mSv worldwide. Only 6-19% of the monitored radiation workers dose in Germany, France, Hungary, Canada are above the instrument detection limit, while China this number reaches 94%. Much effort is needed to improve our individual monitoring in future.

— Individual monitoring in nuclear medicine and interventional radiology

Attention should be paid to the health of nuclear medicine and interventional radiology workers. A cross-sectional survey [13] has reported that the risk of sub-capsular opacity of the eye lens among interventional radiology and nuclear medicine workers was increased significantly compared to conventional radiologists in the hospitals. Some studies [14,15] also reported that compared to other groups, the detection rate of neurasthenia, skin changes, abnormal white blood cell count, unstable chromosome aberration rate, micro-nucleus rate has increased in interventional radiology groups.

— Safety awareness of the radiation workers

With the improvement of ionizing radiation installations and strengthening of radiation protection measures in recent years, the dose to radiation workers has decreased significantly. Some radiation workers did not wear personal dosimeter, as required and some workers think that the monitoring results are too low and of no practical significance so they want to test the sensitivity of the equipment and deliberately place the personal dosimeters under the X-ray beams, making them irradiated. Intentionally misplaced and lost personal dosimeters are not rare.

— Suggestions and conclusions

Support and assist to competent services (including private and commercial ones) [5], make them bigger and gradually solve the problem of excessive fragmentation of monitoring services. Expand the scope of radiation workers, incorporate aircrew and underground miners into the occupational exposure range, so that their health can be protected. The wearing cycle of personal dosimeters should be one month in the workplaces with strong radiation sources, so as to facilitate early detection of excessive doses of radiation and thus reducing or avoiding harm due to irradiation. Strengthen the supervision to individual monitoring services, strengthen proficiency testing inter-comparison between laboratories of individual monitoring services [5]. Intercomparison can help us to understand not only our detection capability, but also the technical level of the domestic services [1]. Communication is useful for learning in each unit, in order to improve the technology quality of individual monitoring services. Implement the quality control measures strictly. Strict quality control is a major component of individual monitoring of external exposure, and we should implement the quality control measures throughout the entire process.

Strengthen research in the monitoring technology of the ring dosimeters and eye lens dosimeters. Carry out monitoring and evaluation of extremities dose and the eye lens dose of interventional radiology and nuclear medicine workers [5]. Carry out monitoring of internal exposure and estimation of dose.

Launch the annu“l "radiation and health science publicity w”ek" activities [17], strengthen the popularization of radiological health laws, regulations and standards through television, network, popular science books and newspapers and other media channels [16]. Relevant measures should be earnestly implemented to improve the radiation workplace awareness of individual dose management, strengthen the organization and coordination, make the management of individual dose interlocking, make individual dose management work more standard and comprehensive, help radiation workers master the basic knowledge of radiological protection and damage due to exposure to ionizing radiation, understand the role and meaning of individual monitoring, eliminate the negative and torpid thoughts, improve their consciousness and initiative to be cooperative with individual dose management, provide a favourable cultural environment for the smooth conduct of individual monitoring work, increase the number of radiation workers who will be subject to individual monitoring according to the law, and to maximize the monitoring coverage rate[18].

Improve the supervision and enforcement of radiation health, give necessary administrative punishment to those who are involved in intentional exposure, artificial exposure, or refuse to carry out the required individual monitoring so as to rectify problems existing in the management of individual dose promptly, and provide legal guarantee for long-term and standardized implementation of individual monitoring.

In brief, much research and technical development in radiation protection dosimetry for workers and the public has been carried out and good progress has been achieved in Ch'na's individual monitoring. Individual monitoring of radiation workers has laid a good foundation after almost 30 years of efforts in China. More comprehensive national regulations, continuous improvement of the quality assurance system, downsizing the number of service providers of suitable personal dosimeters in interventional radiology and nuclear medicine, initiation of radon monitoring of miners among others are needed [19].

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ESOREX — A EUROPEAN PLATFORM FOR OCCUPATIONAL RADIATION EXPOSURES

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Abstract

The European Commission initiated in 1997 the European Study on Occupational Radiation Exposure (ESOREX). The objectives were i) to provide the European Commission and the national competent radiation protection authorities with reliable information on how personal radiation monitoring, reporting and recording of dosimetric results is structured in the European countries and ii) to collect reliable and directly comparable data on individual (levels of individual personal radiation doses to workers) and collective exposure in all occupational sectors where radiation workers are employed (nuclear fuel cycle, medical sector, industry in general, research and education, and natural sources), and investigate the trends and developments of these doses over a period of several years.

INTRODUCTION

The European Commission initiated in 1997 the European Study on Occupational Radiation Exposure (ESOREX). The objectives were i) to provide the European Commission and the national competent radiation protection authorities with reliable information on how personal radiation monitoring, reporting and recording of dosimetric results is structured in European countries and ii) to collect reliable and directly comparable data on individual (levels of individual personal radiation doses to workers) and collective exposure in all occupational sectors where radiation workers are employed (nuclear fuel cycle, medical sector, industry in general, research and education, and natural sources), and investigate the trends and developments of these doses over a period of several years.

The last ESOREX symposium, involving representatives from responsible organizations in all European Union Member States, Associated States and Candidate States, for the collection of dosimetric data and information on occupational radiation monitoring and exposure, took place in Prague (Czech Republic) in 2010. As a result, it was proposed to establish a European Platform for Occupational Radiation Exposures for EU countries, associated countries and voluntary countries, in which representatives from national dose registries and from dosimetry services can discuss emerging issues, assess dose trends and exchange experience.

The European Commission has entrusted the Institute for Radiological Protection and Nuclear Safety (IRSN) with the development of the ESOREX Platform within a 3-year period.

OBJECTIVES OF THE PROJECT

The main objectives of the ESOREX Platform are:

- To allow easy information and experience exchange between experts in occupational radiation exposure, and in particular representatives from European national dose registries and from dosimetry services;

- To assist in the implementation of requirements on occupational radiation protection in the current and the revised Euratom Basic Safety Standards Directive;
- To establish and maintain an overview on national arrangements for occupational radiation exposure in Europe. Such an overview will be helpful for development of arrangements in the different states and then for the harmonization of practices among them;
- To provide the basis for the evaluation and assessment of occupational radiation exposure data with a view to allow for benchmarking exercises and to identify potential for dose reductions (database on occupational radiation exposure). This database shall include data from all participating countries covering all occupational sectors where classified workers are employed (nuclear fuel cycle, medical sector, general research and education and workplaces with natural radiation sources). Such a database on occupational radiation exposure for different sectors will, among others:
    - Allow to identify sectors of interest for all the countries, in which optimization arrangements should be further looked for;
    - Allow to identify sectors to focus on for each country in order to reduce doses compared to other countries; and
    - Allow to prepare the data necessary for more global surveys, as those undertaken by the UNSCEAR.
- To promote the harmonization of data and information reporting formats within Europe and beyond; and
- To establish working relationships with other relevant international organizations and bodies, by taking into account the expectations of these organizations and bodies, in terms of data concerning the occupational exposure of workers in Europe that could be directly available in the ESOREX Platform.

RESULTS AND DISCUSSION

The project started in December 2012. First, a steering group composed of experts was set up and the structure of the platform was designed. The platform consists of a dedicated website with two distinct parts: 1) a database on occupational exposure in the different European countries including information on national regulation, exposure of workers by domain / sector of activity and occupation; and 2) a collaborative tool allowing exchanges between experts in occupational radiation exposure. The input data to be collected and the way to restitute them, as well as the classification of domains /sectors of activity were defined by the steering group. Then, a prototype has been developed by IRSN and tested by the members of the steering group.

The next step of the project will be the organization of a workshop in September 2014. The workshop is intended to offer those representatives from national dose registries in Europe the opportunity to be informed of the progress of the ongoing establishment of the ESOREX-Platform and to share with the project team their experience and view on the prototype which has been developed as well as to discuss the conditions of the sustainability of this Platform on Occupational Radiation Exposure.

OCCUPATIONAL DOSE RECORD MANAGEMENT IN CANADA

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Abstract

In the National Dose Registry has a long and successful history as Canada's repository for occupational dose records. This paper provides an overview of how the Registry operates within the Canadian regulatory structure, followed by discussion on issues, challenges and necessary development to further improve dose record management in Canada.

INTRODUCTION

The National Dose Registry (NDR) is Canada's official repository for occupational radiation dose records [1]. It began in 1951 as part of Health Canada's National Dosimetry Service, which monitors workers in Canada exposed to ionizing radiation. It has since become a separate program within Health Canada and now collects and maintains individual and collective dose records for more than half a million workers, including well over 100,000 who are currently monitored.

The NDR database is administered by the Radiation Protection Bureau of Health Canada within the NDR program, which also supports the following key functions:

- Assisting in regulatory control by notifying Regulatory Authorities of overexposure reports within their jurisdiction;
- Evaluating dose trends and statistics to answer requests from Regulatory Authorities and others;
- Contributing to health research and to the scientific knowledge on risks from occupational exposure to ionizing radiation; and
- Providing dose histories to individual workers and organizations for work planning as well as for compensation and litigation case.

This paper will provide an overview of how the NDR program operates within the Canadian regulatory structure, followed by discussion on issues, challenges and necessary development to further improve dose record management in Canada.

COLLECTING AND MANAGING DOSE RECORDS

The NDR operates independently from the Regulatory Authorities and Dosimetry Service Providers (DSPs) Figure 1 illustrates the division of responsibility between stakeholders for monitoring and regulating exposure to Nuclear Energy Workers (NEW, entirely federal responsibility) versus non-NEWs (provincial, territorial, or federal responsibility). Coordination on the NEW side of the figure is quite straightforward; however, coordination on the non-NEW side can be more complicated.

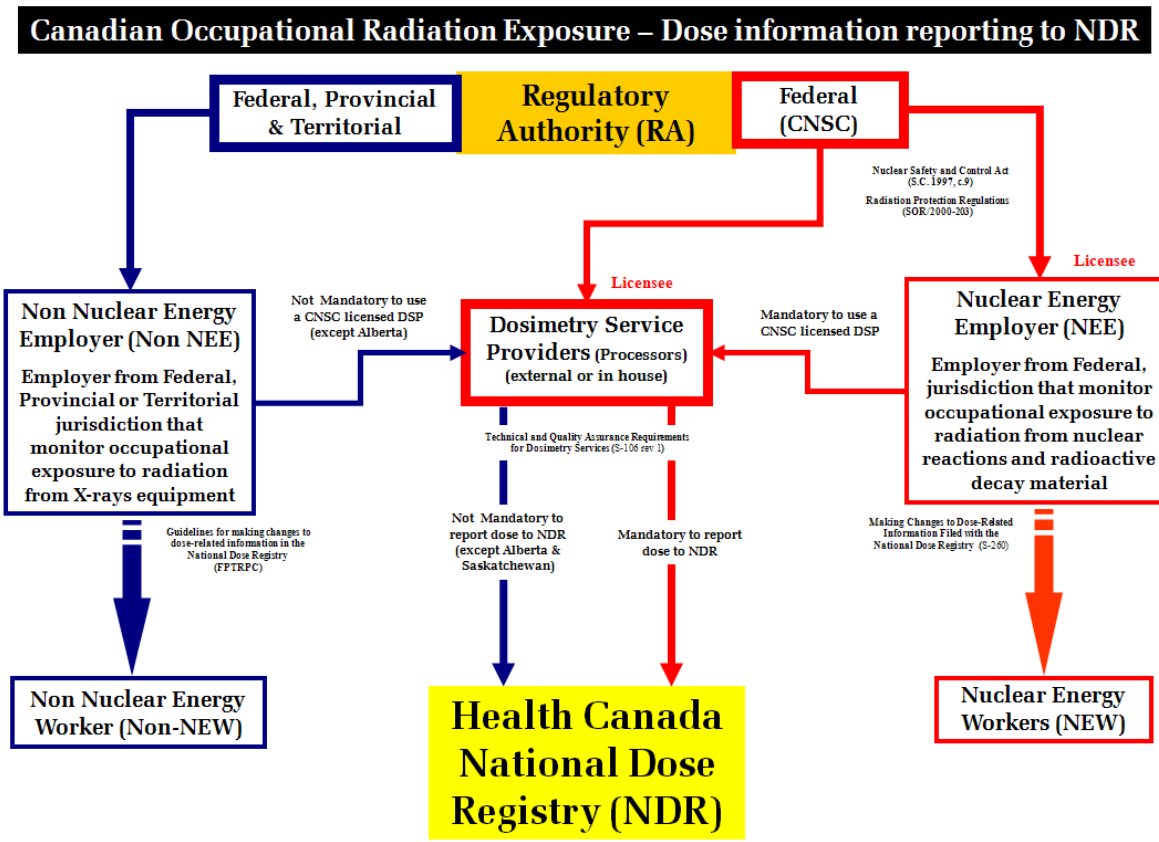

FIG. 1. Regulatory structure in Canada

In Canada, occupational exposure to ionizing radiation is regulated at the federal level for Nuclear Energy Workers (NEW) or for non-NEWs, when the employer is the federal government. In all other cases, occupational exposure is regulated by the provinces and territories, of which there are 13. Practices for dose reporting and maximum exposure limits can differ between jurisdictions, which can create challenges for both collecting data and reporting on high exposures. In order to encourage as much harmonization as possible, NDR is a regular participant in the Federal/Provincial/Territorial Radiation Protection Committee which includes regulatory authorities from all jurisdictions, and is an active member of the associated Radiation Dosimetry Working Group. NDR recently leveraged this working group to successfully negotiate a protocol for submitting dose change requests that has been adopted by all jurisdictions.

To facilitate incorporation of records into the NDR and to enhance quality assurance, DSPs are provided with an Input File Specification that explains exactly how data should be submitted. Data that does not conform to the Input File Specification is rejected and must be fixed by the DSP before it is accepted in the database. Because licensed DSPs are required by the legislation to submit their data to NDR in a compatible format [2,3], DSPs are motivated to correct their data; however, it occasionally requires significant support from NDR staff to resolve this issue. The NDR provides documentation and hands-on training to DSPs to help reduce the number of rejects.

All dose records in the NDR are associated with a worker. To ensure that dose is assigned to the right person and to enable extraction for reporting and research, a unique employee profile is created for every individual registered in the NDR. Social insurance number (a unique, ninedigit code that is required by all workers in Canada) is a critical field. Other personal information, such as name, date of birth and birthplace, is also required and must match within certain pre-established tolerances, which have been adjusted over the years as a result of NDR's operational experience.

Dose Records Information includes type of dose, dose quantities, information about the dosimeter and the monitoring program, and job class, among other things. Job class is a particularly important field for extracting and compiling data for research and, as a result, new job classes are added from time to time to improve the precision with which dose can be correlated with specific types of work. For example, uranium mine has been a job category since 1957 while a job category of non-uranium mine was added in 1981. Currently, there are a total of 112 job classes in 21 job categories.

SNAPSHOT OF CURRENT NDR OPERATIONS

The NDR contains information on 869,735 workers and 35,232 employers, with approximately 160,000 workers monitored in 2013. Each year, 1.25 million dose records are processed and incorporated into the database via an average of 900 batches, and close to 7,000 Dose History Summaries are processed annually and sent to clients via fax and post mail. Every time a new record is entered for an individual worker, their accumulated dose for the current regulatory period is calculated and compared against the appropriate limit. If it exceeds the limit, a High Exposure Notification (HEN) is automatically generated and then immediately transmitted to the appropriate Regulatory Authority for follow-up. On average, fewer than 20 High Exposure Notifications are triggered every year.

NDR data is also used for research, often by external clients [1]. The database structure and required fields enables researchers to quickly compile data sets to evaluate dose trends over a variety of parameters, including specified workplace(s) and/or job categories. As an example, the analysis of average annual doses among Canadian radiological technologists for the past two decades, based on data from the National Dose Registry, is shown in Figure. 2.

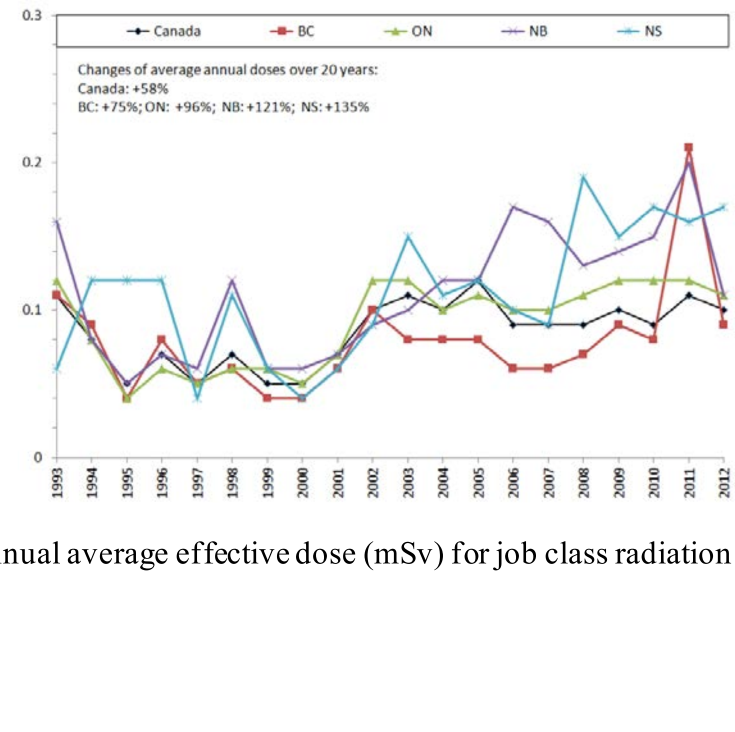

FIG. 2. Annual average effective dose (mSv) for job class radiation technologist

DISCUSSIONS AND CONCLUSIONS

Over the past several years, Health Canada has modernized the NDR in order to adopt new technologies and remain current with legislative requirements and client demands. While they have not been discussed in great detail in this paper, constraints imposed by tighter controls around personal information have been particularly challenging to address. Considerable effort has gone into ensuring that personal information in the NDR is protected and secure, and that NDR protocols conform to all relevant Canadian privacy legislation. One of the constraints imposed by privacy requirements is that access to the database is restricted to NDR staff only. Work is currently underway to identify and implement secure mechanisms to allow access to external clients, especially DSPs (to upload data) and regulators (to query the database). Many agreements have been formalized and safeguards put in place to ensure that arrangements for disclosing personal information are fully in conformance with privacy regulations. A priority for on-going work in this area includes finding a way to allow DSPs to upload batches of new records directly, which would reduce demands on NDR staff.

An additional challenge with respect to data collection is that the requirements for dose monitoring are more prescriptive for the NEWs who have a reasonable probability of receiving an effective dose of greater than 5 mSv in one year than they are for those who are expected to receive less. As a result, there is a risk that low or zero doses are under-reported in the NDR in some job classes. The significance of this issue has not yet been fully explored but will be the subject of future study.

Other plans for the future include developing protocols for registering radiation exposures that are currently excluded from the NDR, including doses received by Canadians outside of Canada and those received by emergency workers responding during a nuclear emergency.

Finally, work will continue to enhance the NDR so as to better address research questions. This includes identifying emerging job titles/classes, new occupations and new applications for radioactive materials in the workplace.

The NDR has a long and successful history as Canada's repository for occupational dose records. Going forward, Health Canada will continue to ensure that the NDR evolves in response to technological, legislative, and operational needs, as it has for decades, and that it continues to play an essential role in protecting the health and safety of Canadian workers.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 4

F. Shannoun

United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), Austria

SUMMARY OF POSTER PAPERS

There was one poster presented in this session, which was entitled "Fifteen years of occupational exposure monitoring in the Federation of Bosnia and Herzegovina". It was a cooperation work of B. Begzada from the Radiation Protection Centre (RPC) at the Institute of Public Health in Sarajevo, A. Beganović and Skopljak-Beganović, both from the Department of Medical Physics and Radiation Safety at the University Clinical Centre of Sarajevo and D. Samek from the Veterinary Faculty at the University of Sarajevo. Their poster summarized the dosimetry results for the past 15 years, starting from 1999 when thermoluminescent dosimetry was introduced in the Federation of Bosnia and Herzegovina, until end 2013. The Data were compiled to match the categories used in the UNSCEAR 2008 Report [1].

The authors stated that monitoring of occupationally exposed persons started in Bosnia and Herzegovina already in the 1960s. It was interrupted in the 1990s and continued in 1999 after the International Atomic Energy Agency (IAEA) provided a thermoluminescent dosimetry reader and a set of thermoluminescent dosemeters (TLD) [2]. Until recently, the only institution that provided personal dosimetry service in the country was the RPC. It covers approximately 70% of all occupationally exposed workers in the country. In December 2013 the RPC monitored 1,485 workers with personal dosimetry, which is over 70% of all radiation workers in the country. In the past fifteen years, the number of TLD users increased steadily, with 73 users per year on average (Fig. 1). Workers are classified into groups according to their profession. 1.417 monitored persons (95%) work in the medical sector (diagnostic and interventional radiology, nuclear medicine, radiotherapy, dentistry and veterinary medicine) while a smaller number are industrial workers.

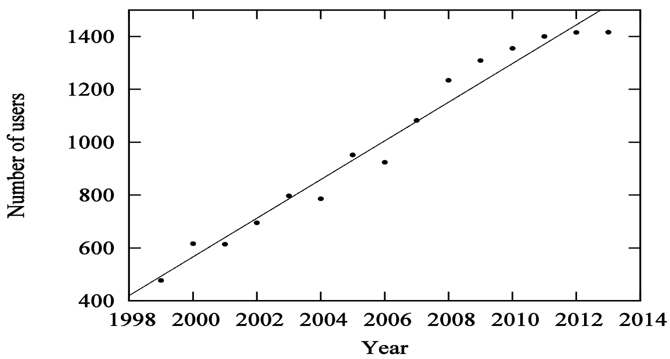

FIG. 1. Increase of number of TLD users in FBiH. The number of occupationally exposed workers covered by TL dosimetry increased by 73 users per year (linear regression curve y=73.16*x*-1.457×105)

The main result of this study is the total number of TLD users who were evaluated for annual doses is approximately 15,000. The majority of the annual doses received were less than 0.99 mSv y^{-1} (96%), some users received doses 1.00–1.99 mSv y^{-1} (3.3%), and very few received doses between 2.00 and 2.99 mSv y^{-1} (0.6%). In some cases, TLD users received doses higher than 3 mSv y^{-1}. On a 5-year average, none of them received annual effective dose greater than 10 mSv y^{-1} and there are no registered cases of exceeding the annual limit of 20 mSv y^{-1}. Persons performing interventional procedures in radiology, cardiology, cardiac surgery and gastroenterology (ca.90 persons) are provided with 2 TLDs that are worn below and above the lead apron. The authors concluded that the results of their analysis have shown an improvement in radiation protection during the last 5 years in their country, which is most likely due to the active involvement of the State Regulatory Agency for Radiation and Nuclear Safety

DISCUSSIONS

The poster has shown the importance of setting up and maintaining a national dose registry. It has been demonstrated during the last 15 years that no individual doses exceeded the limit (20 mSv y^{-1}) and most of the professionals received doses less than 1 mSv y^{-1}. Table 1 shows that the highest doses are associated with professions working in interventional radiology, nuclear medicine and industry.

TABLE 1. COMPARISION OF AVERAGE ANNUAL EFFECTIVE DOSES (mSv) [1,3]

	In mSv			Romania1	Slova-kia1	UK1	Eastern Europe	World 2
Practices	99–03	04–08	09–13					
Diagnostic radiology	0.408	0.428	0.281	0.54	1.79	0.07		
Interventional radiology	0.753	0.585	0.524	3.58	3.72	0.21		
Nuclear medicine	0.553	0.546	0.429			0.59	0.68	0.79
Radiotherapy	0.324	0.349	0.233				1	0.55
Dental practice	0.335	0.322	0.309				0.16	0.06
Veterinary practice	0.681	0.205	0.153					
Industry	0.989	0.498	0.442	2.75	1.60	0.76		

1Data from UNSCEAR Report 2008 [1]
2Data from UNSCEAR Report 2000 [3]

Unfortunately, the authors did not question the relatively high doses received in dental radiology when benchmarking in Table 1 occupational radiation exposure in Bosnia and Herzegovina with data from UNSCEAR [1,3]. However, national regulatory authorities are encouraged to supply data on occupational exposure to UNSCEAR and to use this information for such for comparison.

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CHAIRS' SUMMARY OF TOPICAL SESSION 4

National dose registers provide benefits to workers, employers and regulators. National registers may also be used as indicators of good radiation protection and to monitor the success of optimization. National registers support the requirement for the long-term preservation of worker dose records. They require a well-defined legislative framework for data sharing, data protection to ensure personal confidentiality, and for measures to ensure long-term preservation of worker doses.

The presentations by Spain, China and Canada, together with the poster by Federation of Bosnia and Herzegovina, highlighted the benefits and challenges of maintaining national dose record management systems.

In Spain the National Dose Register was established by the Nuclear Safety Council (CSN) in 1985. It now contains more than 20 million records covering 332,000 workers and 65,000 facilities. The NDR provides long term management of worker dose records, with data provided by the dosimetry services from individual TLD monitoring of workers. Since the dose records are health information, personal data protection legislation applies. Access by workers to their own dose records is possible through the CSN webpage.

China has about 60,000 radiation facilities with more than 300,000 radiation workers. Most of these workers are associated with medical uses of radiation and the nuclear industry. Legislation within China requires individual monitoring of occupational radiation exposure. There are more than 200 individual monitoring providers in China. In 2005, following an IAEA ORPAS mission, the China Register of Radiation Workers (CRRW) was developed under an IAEA CRP activity. The CRRW was officially released in November 2009 and now covers ~90% of workers in hospitals. There are challenges for quality assurance and quality control, particularly for internal contamination, and for the expansion of the CRRW to cover non-uranium miners and air crew.

The Canadian National Dose Register was established in the mid-1970's by the National Dosimetry Service within Health Canada. It now operates independently from the dosimetry service providers and from the regulatory authority. Canadian legislation requires that all licensed dosimetry service providers, nuclear power station operators and uranium mines provide worker dose records to the dose register. The NDR now has information on ~870,000 radiation workers (160,000 workers in 2013) across more than 35,000 employers.

These presentations demonstrated that good coordination of data collection on occupational exposure is required within a well-defined legislative framework for data sharing, data protection to ensure personal confidentiality, with measures to ensure long-term preservation of worker's doses. There are issues with the categorization of workers / work activities, and for the quality assurance of the data. There are groups of exposed workers who not yet monitored (e.g., mines, air crew and some in the medical sector.)

Action: There is significant action required to be done at the national level to set up and maintain a national dose registry. This is applicable to both developed and developing countries.

The two others presentation highlighted international cooperation activities to collect and evaluate data on occupational radiation exposure across national boundaries and globally. The UNSCEAR presentation highlighted the need to have robust database that reflects the real picture of the global situation on occupational radiation exposure. UNSCEAR has conducted assessments of global occupational radiation exposure since 1975, based on information from the 194 UN Members States and the published peer-reviewed literature. The surveys include man-made sources of radiation and more recently, exposure to natural sources. The UNSCEAR will be undertaking an updated evaluation with the aim of providing a comprehensive estimate of world-wide occupational dose distributions and trends. UNSCEAR has reiterated the need for a good international coordination and cooperation of all national authorities for data collection on occupational radiation exposure. A questionnaire for the collection of worker data will be Member States through the national contact points.

The European Study on Occupational Exposure (ESOREX) was initiated by the European Commission in 1997. A recommendation in 2010 for a sustainable platform has resulted in the establishment in 2014 of a WEB-based platform for exchange of information between EU national dose registers. ESOREX was shown as a good example on how to synergize efforts on a regional level to collect and evaluate data on occupational exposure.

Action: National authorities should be encouraged to support UNSCEAR and ESOREX by sharing information on occupational exposure.

TOPICAL SESSION 5:
OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL RESEARCH AND EDUCATION FACILITIES

Chairpersons: C. Flannery, United States of America and M. Farley, ICNDT

OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY – A REVIEW AND RECOMMENDATIONS

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Abstract

Industrial Radiography (IR) plays an important role in ensuring the safe and efficient use and operation of products and production facilities. In this way IR significantly contributes to the protection of the health and safety of workers and members of the public as well as to the protection of the environment. When proper radiation protection programs are in place, the risk of exposure of workers to ionizing radiation can be minimized to an acceptable level. The improvement should be on the prevention of radiation incidents and the minimization of the severity of the consequences thereof. This paper discusses a review of the current status of radiation protection in industrial radiography as determined via a survey that was conducted by the Working Group Industrial Radiography (WGIR) of the ISEMIR project of the IAEA. Recommendations given by WGIR as well as those given during a technical meeting held at the IAEA in June 2014 are discussed. These recommendations include the development of an international database with web-based access for NDT companies, a road map tool that NDT companies can use to identify areas of improvement, the development of an international standard for training on radiation safety in industrial radiography and a review of the effectiveness of the implementation of ISO 3999 in the prevention of radiation incidents.

INTRODUCTION

Non-Destructive Testing (NDT) is applied in a variety of industries including oil and gas, chemical, aerospace, defence, power generation, marine, manufacturing and automotive industries. The objective is to determine the integrity of materials, components and structures such as vessels, pipes, welded joints and castings in a non-invasive way. The information obtained from NDT is used to make decisions on maintenance, repair and replacement of the tested objects. NDT plays an important role in ensuring the safe and efficient use and operation of products and production facilities. In this way NDT contributes significantly to the protection of the health and safety of workers and members of the public as well as to the protection of the environment.

There are different NDT methods which are based on different physical principles [1,2]. Subsequently each NDT method can be implemented with different NDT techniques. Radiographic Testing (RT) or Industrial Radiography (IR) is a method which is obviously based on the use of ionising radiation and its physical characteristics. The mostly used RT techniques are x-ray radiography and gamma-ray radiography. IR can be performed in shielded enclosures or in the field / at a customer's site.

Under normal operations and with proper procedures in place the exposure of workers to ionizing radiation can be kept low and the risk will be acceptable. Even in the case of a deviation from normal operations, the exposure to workers can be kept low if proper emergency procedures are in place. However, experience shows that incidents involving industrial radiography sources have sometimes resulted in high doses to workers, causing severe health consequences such as radiation burns and, in a few cases, death. Overviews and descriptions of such accidents are given in various publications of the IAEA [3-6] as well as on their NEWS website [7]. A useful classification of the primary causes of accidents can be found in a relevant reference [6]:

- Inadequate regulatory control;
- Failure to follow operational procedures;
- Inadequate training;
- Inadequate maintenance;
- Human error;
- Equipment malfunction or defect;
- Design flaws; and
- Wilful violations.

Industrial radiography work by its nature is often carried out under difficult working conditions, such as in confined spaces, at height or extreme cold or heat. Working under such adverse conditions might result in operational situations in which the principle of keeping doses as low as reasonably achievable is challenged. All of these aspects demonstrate the necessity for senior management to promote a safety culture within their organizations to ensure that safety comes first.

In this paper we will review the current situation with regard to radiation protection in industrial radiography. This review is mainly based on a survey that has been conducted by the Working Group Industrial Radiography (WGIR) of ISEMIR [8-10]. Based on that review and on the report of the technical meeting that was held in June 2014, we will discuss some recommendations for improvement.

REVIEW OF CURRENT STATUS OF RADIATION PROTECTION IN INDUSTRIAL RADIOGARPHY

In 2010 a Working Group Industrial Radiography (WGIR) was formed under the ISEMIR project of the IAEA. The objective of WGIR is to support the NDT industry in keeping both the dose due to normal exposure and the risk of exposure due to radiation accidents during the performance of IR as low as reasonably achievable (ALARA). There was also agreement that the focus of the efforts of WGIR should be on the prevention of accidents and the minimization of the severity of the consequences thereof.

As part of its initial actions WGIR conducted a worldwide survey to gain insight into the current practice of occupational radiation protection in IR. Three different questionnaires were sent respectively to Regulatory Bodies, NDT companies and individual radiographers. The final draft of Special Safety Guide 11 on Radiation Safety in SSG-11 [11] was used to draft the questionnaires that covered the following categories of subjects:

- Qualifications and training of radiographers in radiation protection;

- Learning from incidents (accidents, near misses, deviations from normal operations);
- Systems and procedures in place for safe operation;
- Emergency preparedness and response;
- Individual monitoring.

The results from the survey need to be interpreted with caution as the methods of questionnaires distribution to radiographers and NDT companies probably mean that those that responded, represent the better end of the practice spectrum. Nonetheless, the main findings can be summarized as follows [8,9]:

- Initial radiation protection training for radiographers is reasonably well established, but there is room for improvement especially with respect to refresher training and practical emergency response training;
- The frequency of occurrence of incidents (accidents, near missed and deviations) is not trivial, and methods such as better incident reporting, analysis, feedback and sharing lessons learned need to be better utilized;
- Collimators and diaphragms are not being used as often as they should be;
- Survey meters are not as widely available as they should be and improper use of survey meters is mentioned by both NDT companies and regulatory bodies to be one of the most common shortcomings found during inspections;
- Individual monitoring, as reported, is well established, with passive and active dosimeters. The establishment and use of investigation levels needs to be improved;
- Warning systems to prevent entry to the work area during site radiography were not always as effective as desired. Better communication at the site is needed;
- Emergency plans were widely prevalent, but there seemed to be some issues regarding specific training for radiographers with respect to emergencies;
- Occupational doses received by radiographers varied considerably, with no correlation with radiographic workload.

In 2014 the IAEA published a TECDOC on the work of WGIR [8] in which all the data and analysis thereof is presented. The conclusion of WGIR is that there is a need for considerable improvement in occupational radiation protection, especially in the implementation of optimization of radiation protection. For that reason, WGIR developed two tools: an international database and a road map [10].

RECOMMENDATIONS FOR IMPROVING RADIATION SAFETY IN INDUSTRIAL RADIOGRAPHY

— Recommendations from ISEMIR Working group

(a) International database

One of the long-term objectives of the ISEMIR project is the development of an international database. This database should provide end-users of various applications of ionizing radiations, i.e. including but not limited to Industrial Radiography, a web-based tool with which they can improve their radiation protection programs. As resources permit, the database for IR is to be developed in three stages.

The first two stages should enable the collection of data on the doses, workload and radiation protection program of NDT companies and allow statistical analysis, benchmarking and reporting tools. The metric proposed for assessing the effectiveness of the optimization will be the (average) occupational exposure per radiographic exposure for a (group of) industrial radiographer(s). The performance can then be statistically assessed as a function of parameters such a training, use of survey meters and collimators, percentage of site radiography, etc. The third stage would be the development of a module for incident reporting and analysis as well as for sharing the lessons to be learned from incidents.

(b) Road map

The idea of a road map came from the development and analysis of the questionnaire that was distributed amongst NDT companies. The road map will be a software tool with which an NDT company can compare elements of their radiation protection program with the accepted practice by answering a series of questions on different topics. The accepted practice for each question is based either on the relevant third quartile value from the distribution of responses from the survey or on a value given in an international standard. As the relevance or importance of questions for optimization of radiation protection may vary, the WGIR applied different weightings to the questions. Based on its weighted score on the different topics an NDT company can identify areas for improvement. The road map is also proposed as a way to give something back to the NDT companies that contribute to the database.

More information on the International Database and on the Road Map can be found in the aforementioned TECDOC [8].

— Recommendations of the technical meeting on industrial radiography

In June 2014 a Technical Meeting was organized at the IAEA on Radiation Safety in Industrial Radiography. There were sessions on training, equipment, emergency response, regulatory infrastructure and the safety/security interface. Furthermore, there were two breakout discussion groups respectively focusing on:

- A review of the current IAEA documents relevant to radiation safety in industrial radiography;
- Training material needs and desires for industrial radiography practice. The input from all sessions and discussions resulted in recommendations for further actions by the IAEA [12].

One of the recommendations is the development of an internationally recognized training standard for safety in industrial radiography operations. In my point of view we should have a standard similar to the already existing ISO standard for qualification and certification of NDT personnel for applying the different NDT methods and techniques [2]. It should contain requirements for training at different levels and for different roles, i.e. assistants, radiographers, RPOs, persons involved in equipment maintenance and persons involved in source retrieval. The benefit of such a standard would be that there is an internationally recognized baseline for the required radiation safety competencies for the performance of the different roles. Another benefit could be that an international standard contributes to the mutual recognition of training respectively between and received in different Member States (apart from knowledge of local rules).

Another recommendation is that the IAEA should take appropriate actions to encourage adoption of the equipment standard ISO 3999 [13] in the Member States as a means of international certification. At the suggestion of Applus RTD [14] it was agreed that at the start of such a project, it would be beneficial to review the effectiveness of the implementation of ISO 3999 in the prevention of accidents or minimizing the severity of consequences. The reason is that in our experience the safety devices prescribed in ISO 3999 can also fail. Failure of safety devices will lead to unsafe operations potentially leading to radiation incidents. Subsequently the safety devices make source retrieval more complicated, potentially leading to more severe consequences of the radiation incidents. Questions to be answered during a review should therefore include:

- Is there a correlation between radiation incidents in recent years and equipment compliance with ISO 3999?
- Do the tests described in the standard sufficiently account for the conditions under which the devices are used in the field?
- Are exposure devices always manufactured and repaired according to design specifications, e.g. with respect to the quality of used materials and tolerances in the production of its constituting (spare) parts?
- Are end-users, - in particular radiographers, persons involved in maintenance and persons involved in source retrieval - sufficiently involved in determining the design criteria of radiography equipment to make use of their knowledge and experience?

Similarly, to the conclusions of the survey conducted by the WGIR, an observation made during the technical meeting was that the proper use of radiation survey meters requires improvement. During the meeting it was therefore suggested that it might be beneficial to determine, if possible, the circumstances and reasons why radiographers do not always use radiation survey meters in order to avoid accidents. For the other comments and recommendations, the reader is referred to the Chairman's reports [12].

CONCLUSIONS

With a proper radiation protection program in place industrial radiography can be performed with minimal risk for workers. However, from an international perspective there is still considerable opportunity for improvement of radiation protection programs and the implementation and harmonization thereof. The IAEA with the support of its Members States appears to be the organization to support the companies and individuals involved in the performance of IR to achieve this improvement. The fact that the IAEA specific safety guide on Radiation Safety in Industrial Radiography [11] is now being incorporated in the national regulations of various countries shows that this is feasible.

Various recommendations are given to the IAEA for further actions. The Working Group Industrial Radiography of the ISEMIR project could play a significant role in the implementation of these actions. A main challenge is to achieve a further and broader involvement of the NDT industry.

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ISSUES IN OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY — A REGULATOR VIEW

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Abstract

On 23 September 2009, the UAE issued Federal Law by Decree No. 6 of 2009 on the Peaceful Uses of Nuclear Energy that set in place the framework for nuclear regulation and formally established the nuclear regulatory body, the Federal Authority for Nuclear Regulation (FANR) as being responsible for the oversight of radioactive sources and radiation generators used for industrial, medical and other purposes. FANR is also a 'new' organization for the control of the use of radiation sources, replacing the former authorities (Federal Environmental Agency and health authorities). There are different approaches which have been created and adopted by FANR to develop the Occupational Radiation infrastructure in the country to be able to support the controlling of the issues and challenges related to the radiation protection in all practices including industrial radiography.

INTRODUCTION

The licensing process started in May 2010 after FANR established the regulatory framework including FANR-REG-24 "Basic Safety Standards for Facilities and Activities involving Ionizing Radiation other than in Nuclear Facilities" which is based on IAEA BSS, as well as on FANR-RG-07 "Safety Guide", describing the methods and/or criteria acceptable to the Authority for meeting and implementing specific requirements in the Authority regulation.

FANR has issued a specific regulatory guide FANR-RG-019 on Radiation Safety in Industrial Radiography (based upon the IAEA's Specific Safety Guide SSG-11) to support radiation protection in this practice by providing acceptable methods and guidance for meeting the requirements of the Authority's regulation (FANR-REG-24).

There are around 80 companies (out of a total of 750 Licenses) authorized for Industrial Radiography using Ir-192, Se-75, Co-60 and X-ray units. Currently FANR is assessing the first application to use a linear accelerator for this purpose to replace the use of a Co-60 source. There are around 2000 occupational exposed workers in this field and all of them are expatriates.

DEVELOPMENT OF ORP INFRASTRUCTURE

The UAE's Service Providers sector is not fully developed yet. FANR is in process of issuing criteria to manage and control this sector. The criteria will cover dosimetry, calibration, certification and training services in radiation safety.

As of 2015, it is expected that service providers, along with Licensees, will be subject to accreditation requirements and some dosimetry services to be provided by the UAE Secondary Standard Dosimetry Laboratory (SSDL). The UAE is working on setting up an SSDL, which is currently under construction, and it's expected to be completed and fully operated by 2015. For the time being, all the licensees send their equipment abroad for calibration.

In order to facilitate the development of a market for authorized Service Provider’s in UAE, FANR believes that there is a need to set up the necessary legislative framework for this purpose.

— Dosimetry services

The assessment of occupational exposure is an essential part of Occupational Radiation Protection. In the UAE, there are currently three local dosimetry Service Providers. However, none of them is either recognized in the UAE or accredited abroad. FANR-REG-24 requires the licensees to ensure that “adequate arrangements are made with dosimetry services that operate under an adequate quality Management System, and are approved by a certifying organization acceptable to the Authority” [1].

Currently, FANR does not grant approval or authorisation to Service Providers to conduct individual dosimetry monitoring. FANR is developing criteria to be fulfilled by dosimetry service providers to improve monitoring and recording of occupational exposures in planned exposure situations.

Moreover, a web-based National Dose Register for occupationally exposed workers is currently under development by FANR. FANR has also developed arrangements with dosimetry Service Providers to report directly to FANR any doses exceeding the dose limits.

— Radiation safety training

The FANR is working on developing the training infrastructure in the UAE in cooperation with local stakeholders and through the National Radiation Protection Committee, by establishing a National Training Strategy on Radiation Safety. To support the development of training in the country, especially in the absence of an approval system for training providers, a guide on training requirements for each practice, position and a list of available Training Providers are published on FANR website.

— Outreach

FANR is keen to maintain communication with the licensees in order to enhance radiation safety. For this purpose, FANR has regularly conducted a workshop, named “Meet Your Regulator”, to familiarize the licensees and the applicants with the regulatory requirements and to respond to their questions in relation to licensing conditions, inspection, licensing process and training.

During the last workshop “Meet Your Regulator” one of industrial radiography licensees shared its experience about an incident involving a lost radioactive source (Ir-192, 73 Ci), which was successfully recovered and lessons drawn from this experience, especially with action taken to report the incident, recover the source, and more importantly, maintain transparency with the regulator and licensees alike.

Keeping open communication channels between the Regulator and Licensees is very important to establish mutual trust and enhance the safety culture.

CHALLENGES AND GENERAL ISSUES IN INDUSTRIAL RADIOGRAPHY PRACTICE

Operators, as well the Regulatory Authorities, face challenges to improve the occupational radiation protection in industrial radiography practice. The following are some approaches that have been adopted by FANR to achieve this goal.

Direct Reading Dosimeters: the dose records of the workers in industrial radiography practice show that there can be cases where the doses exceed individual exposed workers' annual effective dose limit (20 mSv/y) on a frequent basis. Using a passive dosimeter does not indicate if there is a high level of radiation in an area. FANR is working with the licensees to resolve this issue. In the majority of cases, where there frequently occur high doses, licensees have agreed to use electronic dosimeters in parallel with the passive dosimeter, to get timely warning about high radiation level. While for licensees it is a financial burden to supply electronic dosimeters, for the Regulatory Authority it is an urgent task, especially when the licensees failed to take other corrective actions.

Responsibility of workers: FANR has only recently included the responsibility of workers for radiation safety in FANR-REG-24 rev.1. This requirement has been added in the regulation based on IRRS recommendation and aims to create a balance of responsibility for radiation safety between the licensees and their workers. It also helps avoiding a blaming culture and promotes the safety culture in the organization.

Proper assessment of high dose readings: inadvertently leaving the passive dosimeter near a radiation source is the most frequently stated cause of recorded high doses. The efforts are needed from both Licensees and the Regulatory Authority to identify and assess these incidents and as far as possible to prevent repetition of such events.

Training on radiation safety issue: the requirements of training in Radiation Safety for industrial radiography practice is identified by FANR through two means: First is FANR-RG-19 "Radiation Safety in Industrial Radiography" which explains the requirements for Radiation Safety Training required by Assistant Radiographers, Radiographers and Radiation Protection Officers, in addition to the information published on FANR website about the training requirements for each practice, including industrial radiography. Yet the workers in industrial radiography practice find difficulty in understanding the Radiation Safety requirements. FANR will put more efforts in this subject in cooperation with other stakeholders.

The most important issues facing industrial radiography practice in UAE with respect to occupational radiation protection are summarised in the following points:

Safety Culture issue: the workers usually do not report to their management any mistakes relating to their work activity. There is a gap in communication and lack of trust between employers and their workers.

Communication issue: all of the industrial workers in the UAE come from other countries and most of them are neither Arabic nor English speakers. This makes it difficult for the Regulatory Authority and the Licensee to be able to ensure the effectiveness of the radiation safety instructions and procedures and to deliver effective training.

CONCLUSIONS

It is always a challenge to control the Occupational Radiation Protection in industrial radiography practices due to the nature of the risk associated with it. For that purpose, FANR used one of the IAEA tools to assess the occupational radiation protection infrastructure in the country and based on IRRS suggestion to have IAEA Occupational Radiation Protection Appraisal Service (ORPAS) mission, in order to define an action plan for further development of the occupational radiation protection infrastructure. The scope of the mission selected one of the industrial radiography companies (as end user) and individual monitoring service provider to be assessed during the actual mission in October 2015.

FANR tries to implement robust licensing and inspection processes in the Country by adopting the best practices, training its employees and effectively spread the safety culture concept among the users of radiation sources.

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TRAINING AND EDUCATION REQUIRMENTS FOR OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL RADIOGRAPHY

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Abstract

Non-destructive testing (NDT) is the determination of the structural integrity of material or components using non-destructive techniques, e.g. radiographic testing (RT). For industrial radiographic testing X-ray and gamma devices are used. Gamma devices for NDT contain sealed radioactive sources with high activities of several TBq. The X-ray devices provide radiation energy up to 300 keV. Due to the potential risk in working with such sources many requirements on their safe handling are stipulated. This includes equipment technologies and in addition to basic knowledge of radiation protection for every person handling a radiation source, and enhanced training for the responsible persons in radiation protection. A profound training in combination with work experience and up-dated courses is one step towards safe handling of sources and establishing a valid organization of radiation protection in a company. In Germany, every Radiation Protection Officer (RPO not equivalent to 2013/59/EURATOM) is liable for his in-plant authority. This is a challenge especially for on-site industrial radiography. Knowledge in radiation protection is proved by written exams during a course. Working experience is much more difficult to ensure. One option is the certification of NDT personnel.

TRAINING REQUIREMENTS

There are several guidelines; codes etc. are dealing with training on radiation protection and industrial radiography. Training on radiation protection is usually required by law, like in the European Union (e.g. EURATOM Council Directive 96/29/EURATOM and 2013/59/EURATOM). Training on industrial radiography goes on without any legal regulation. This seems to make harmonization of training easier. Of course, every member state of the EU has to implement the EURATOM Council Directives into national law. However, there has always been and will be a wide space for interpretation (e.g. Radiation Protection Experts / RPE and Radiation Protection Officers). Training on industrial radiography is based on DIN EN ISO 9712, therefore training in different countries can be accepted for certification.

— Training Requirements – Radiation Protection (Germany)

In Germany, law requires training on radiation protection. This is based on the implementation of the EURATOM Council Directive (96/29/EURATOM) into German law. In Germany radiation protection is subject to the Atomic Law (AtG, 2010), [1] Radiation Protection Ordinance (2012) 0 and X-Ray Ordinance (2011) [2]. The German Training Guidelines according to Radiation Protection [3] and X-ray Ordinance [4] define range and content of each radiation protection (RP) course, according to the subsequent scope of the trainee, the greater the responsibility the longer the RP-course. In Germany a distinction is made between the licensee (the company´s management respectively Radiation Protection Supervisor / RPS) who needs no training but is liable, the responsible person for the whole company regarding RP

(Radiation Protection Officer / RPO for overall direction) and the responsible person during on-site operations (Radiation Protection Officer / RPO on-site). There is also a distinction regarding the potential risk handling the radiation source (gamma-radiography vs. X-ray-radiography) and the education (e. g. apprenticeship or academic studies). A higher training qualification will reduce the experience time.

TABLE 1. RADIATION PROTECTION TRAINING AND EDUCATION REQUIREMENTS IN GERMANY

	RPO Overall Direction	RPO On-Site
Gamma-Radiography	Training: 5 d Education: technical or scientific Work experience: 3 - 12 month	Training: 4 d Education: not specified Work experience: 3 - 12 month
X-ray-Radiography	Training: 4 d Education: technical or scientific Work experience: 6 - 8 month	Training: 2,5 d Education: not specified Work experience: 4 - 8 month

The distinction between RPO “overall direction” and “on-site” is only made by the German Training Guidelines, whereas the Radiation Protection Ordinance knows both as RPOs which are liable. To become a RPO passing the RP-course will not be sufficient, to get the recognition from the competent authority is also required. Additionally, the future RPO has to approve his reliability, education and work experience. Unlike the recommendations of the 2013/59/EURATOM, in Germany their competence is recognised by the competent authority, therefore we lack a Radiation Protection Expert. The Radiation Protection Officer as defined in 2013/59/EURATOM is comparable to the person handling radiation sources, who is once a year instructed in RP and in the equipment technologies. In Germany not only the RPOs, but also the RP-courses are recognised by the competent authority, every course has to be officially approved following the Training Guidelines. The structure of RP in Germany shows the following figure.

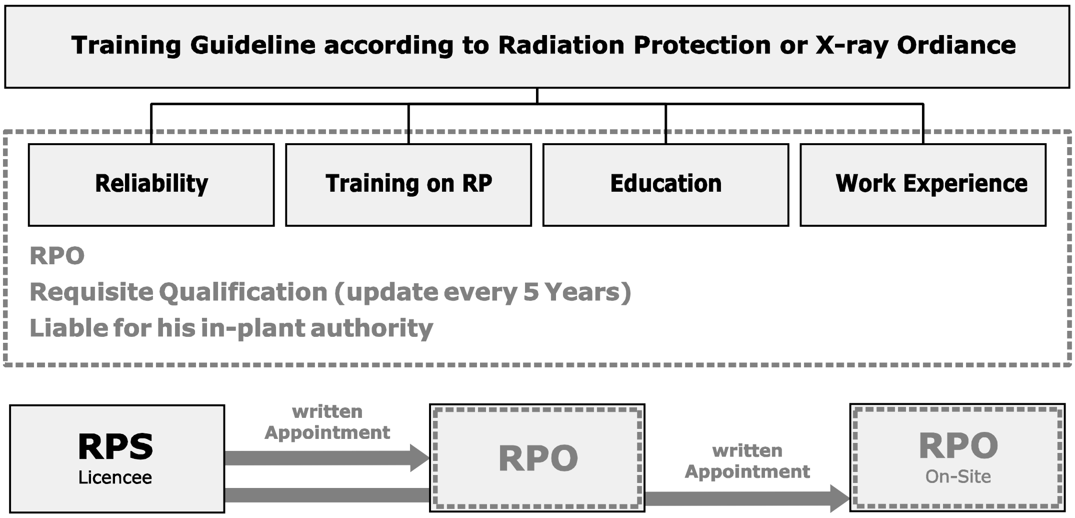

FIG.1. Radiation protection training guideline in Germany

— Training Requirements – Industrial Radiography

Several organizations provide guidelines for qualification and certification of personnel for non-destructive testing (NDT) as the IAEA, EFNDT, ICNDT, etc. This presentation is limited to the European standard EN ISO 9712 [5]. Similar to the field of radiation protection, certification in radiographic testing (RT), respectively industrial radiography requires training and work experience. It is also possible to reduce industrial NDT experience (work experience) and even the duration of training by appropriate education (e.g. graduation in a relevant subject from technical college or university), an overview is given in [6].

TABLE 2. RADIOGRAPHY TRAINING REQUIREMENTS*

RT Level	Training in h	industrial NDT experience in month
1	40 20 (e. g. graduated)	3
2	40 + 80 20 + 40 (e. g. graduated)	3 + 9
3	40 + 80 + 40 20 + 40 + 20 (e. g. graduated)	3 + 9 + 36 3 + 9 + 18 (graduated)

*According to ISO9712.

As shown in [7] the NDT training, qualification and finally certification is organized in three levels:

- LEVEL 1: competence to carry out RT according to written instructions and under the
- supervision of Level 2 or Level 3 personnel;
- LEVEL 2: competence to perform RT according to NDT procedures; and
- LEVEL 3: competence to perform and direct NDT respectively RT operations

The certification of NDT personnel is a task of third-party organizations, not competent authorities, contrary to RP. The employer confirms the industrial NDT experience of his employee for certification, which is based on a 40 h/week or legal week of work [8]. The validity of the certificate is five years, after a period of renewal (fifth year) the certified person has to pass a recertification exam (tenth year). The employer has to confirm the industrial NDT experience for the whole period (no gap longer than one year allowed).

RADIATION PROTECTION AND NDT IN PRACTICE

The personnel for industrial radiography are trained in equipment technologies and radiation protection. In case of being Radiation Protection Officer his knowledge is approved by the competent authority. If the personnel is certified in radiographic testing (level 1 to 3), additional working experience (industrial NDT experience) and training is approved. The organization of radiation protection and NDT is a responsibility of the company. This leads to various combinations of RP and NDT qualifications. Whereas the typical “on-site” radiographer has both qualifications (RPO “on-site” and RT level 1 or 2), for a RPO “overall direction” the radiation protection might be the only point of contact with NDT.

Regarding on-site radiography the RPO is not only responsible of supervising the controlled area, dosimetry, documentation, shielding and first reactions to incidents, he also performs radiographic testing. This is the reason why, in Germany, as a minimum two persons are required for the on-site radiography. It could be discussed, if a 4-day RP-course covers all needs of an on-site RPO. Therefore, the responsibility of the employer (instructions, ensure sufficient work experience) gains importance.

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OCCUPATIONAL RADIATION PROTECTION AT ACCELERATOR FACILITIES — CHALLENGES

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Abstract

Accelerators are being widely utilized in the world for various applications in industry, medicine, food preservation, agriculture and basic & applied research. Accelerators used in industries are of low or medium energies, up to about 10 (MeV), but operated at power levels typically of kilowatt (kW) level. Those used in basic and applied research have particle energies up to several (GeV) or even up to (TeV), where the beam power is usually not high as that of industrial accelerators. In general, the radiation environment in particle accelerator facilities depends mainly on the type of particles accelerated, beam power, beam loss scenario and the type of target specimens used for experiments. High energy, synchrotron, high power proton accelerators for Spallation Neutron Sources and Accelerator Driven Sub-critical Systems, laser plasma driven by accelerators are also gaining attention worldwide. The challenges faced in these facilities mainly are very high dose rates, high energy of particles, pulsed structure, highly collimated, mixed field, induced radioactivity and toxic gas generation etc. The paper describes the radiation environment of different types of particle accelerators and challenges faced by radiation protection professionals.

INTRODUCTION

Today there is a growing need in the use of accelerators for various applications in the field of medicine, industry, defence, environmental sciences, food processing and in basic & applied research. Already 30,000 accelerators worldwide are in use in the area of medicine (diagnosis & therapy) and industry only [1]. Besides, hundreds of accelerators in several national laboratories are used for basic research [2]. In particular electron accelerators are widely used nowadays in the field of medical diagnosis, therapy, industrial radiography, basic research, production of radioisotopes for nuclear medicine and synchrotron radiation etc. For applications in medicine, industry and food processing, the energy of the accelerated electrons is usually less than about 10 MeV [3], whereas it may extend to several TeV for research applications [4]. In the famous "Livingston plot", a tenfold increase in accelerated particle energy was predicted every seven years [5]. The increase in the use of such machines with higher accelerated energy and pulsed in nature raises several safety issues [6]. For example, in new generation synchrotron radiation sources and colliders, the accelerated energies are very high and when these particles interact with accelerator structures, they generate a cascade (electromagnetic cascade) of secondary particles, with energies extending up to several hundreds of MeV or GeV, intense and directional. The particles may include bremsstrahlung x-rays, neutrons, pions, muons, annihilation photons and induced radioactivity. This complex radiation environment sophisticates the radiation protection programme in such facilities. Electron accelerators which are operated below about 10 MeV the cascade generation is of less importance. However, bremsstrahlung radiation is the main radiation hazard in such accelerators. Radiation environment and safety issues at low to medium energy electron accelerators are elaborated in IAEA Tech rep. series 188 compiled by W.P Swanson [7] and in

NCRP Report 51 [8]. Similarly, for high energy electron accelerators, the safety and shielding issues are compiled in ICRU 28 [9], NCRP 144 [10], A.H. Sullivan [11] Vylet & James Liu [12] A. Fasso et.al [13]. The radiological safety issues of electron synchrotron radiation facilities are elaborated in literature [14-17]. Proton and heavy ion accelerators are used in basic and research and now they are gaining importance in nuclear medicine as well as in therapy. Cyclotrons are widely used for the production of PET isotopes and heavy ions are gaining importance in used in hadron therapy. It is also important to note that high energy proton accelerators are now being used for the production of intense neutron sources, called Spallation Neutron Sources (SNS) [18] and being considered for Accelerator Driven Subcritical Systems (ADSS) [19]. The talk describes the radiation environment of different type of accelerators and the challenges faced by radiation protection professionals at those facilities.

RADIATION ENVIRONMENT AT ACCELERATOR FACILITIES

Radiation environment in accelerators depends on the type of particles accelerated, energy, the beam current and the type of interaction with the accelerator structures or experimental target samples. The source term depends on the beam losses occurring at various stages of the acceleration process. Radiation produced in accelerator facilities can be broadly classified as prompt (emitted during accelerator operation) and residual radiation (present even after the accelerator is put off).

— Electron accelerators

In electron accelerators the prompt radiation of major concern are bremsstrahlung photons followed by photo-neutrons [7]. At low energies, electron mainly interacts through collision loss, which is the combined effect of ionization and excitation. Once the energy exceeds a critical energy, electron loses its energy mainly by radiation emission [9] or bremsstrahlung x-ray emission. The collision and the radiative loss for a given atomic number, Z are equal at the critical energy, Ec (MeV) = 800 / (Z+1.2). For example, in the case of lead (Z=82), the two losses will be equal at about 9.6 MeV. Therefore, in high energy electron accelerators, bremsstrahlung radiation is the main radiation hazard. Bremsstrahlung photons have a broad spectrum of energies extending up to the electron energy and are highly forward peaked. At about 1 MeV the intensity of bremsstrahlung from a thick high Z target is same in the forward and lateral direction [10]. As the energy is increased, the intensity peaks in the direction of incident beam. Moreover, the spectrum of radiation is harder in the forward direction and becomes softer at wider angles. High-energy photons in the bremsstrahlung spectrum will most likely interact by pair production. The photon will produce an electron - positron (e^+, e^-) pair after traveling an average distance of $9/7X_0$ [9]. Both the electron and positron will generate bremsstrahlung photons again as it traverses through the medium, which in turn produce (e^+, e^-) pairs. The process of bremsstrahlung photon generation and pair production continues to take place and a cascade or shower of positrons, electrons and photons will develop within the absorber medium. The number of particles in the cascade approximately doubles at each step until the electron energy falls below the critical energy, Ec, beyond which the electrons undergo mostly collision, and the photons undergo mainly Compton scattering and photoelectric absorption. The effect of the cascade generation on an exposed human body is that the depth dose curve in the body has a raising and falling edge where the maximum dose occurs deep inside the body with a dose build up w.r.t the surface dose [20].

During the cascade process, as the photon energy is higher than the photo-neutron production threshold (typically about 10 MeV in most cases) photo-neutron also contributes to the prompt radiation hazard. The detailed mechanisms of photo-neutron generation are described in literature [7, 21–23]. Important point to be noted here is that though the cross section for the process is of the order of a few millibarn, neutrons of energy as high as hundreds of MeV are generated. As the cross-section for photo-nuclear process is less, induced activity issues are not of significance in electron accelerators. In low energy, high power electron accelerators, where the primary beam is brought out in air produce noxious gases like ozone [7] in significant amounts, which limits entry to the accelerator hall after putting off the accelerator. Though radioactive gas ^{13}N and ^{15}O formation is possible due to (γ, n) reaction with a threshold of 10.55 MeV & 15.67 MeV respectively, they are usually of negligible concentration. However, estimation of the concentration has to be carried out for the same. An estimation of activity produced in cooling water also is desirable as the activity builds up due to tritium ($T_{1/2}$:12.26 years).

— Proton and heavy ion accelerators

In contrast with electron accelerators, the major prompt radiation in proton and heavy ion accelerators are neutrons [10, 24]. Though the radiation environment of proton and heavy ion accelerator is similar, the magnitude of neutron generation in proton machines are several order magnitudes higher than that of heavy ion accelerators, as the intensity of protons are usually higher and has low coulomb barrier for target nuclei. Also, the energy per nucleon achievable by protons are high than heavy ions. Though gamma rays and other secondary particles also contribute to the prompt radiation, they do not pose as a radiation safety issue outside the shielding. Neutrons are generated mainly through nuclear reactions at lower proton energies (higher than the coulomb barrier) whereas at higher energies above hundreds of MeV, many secondaries are generated through hadronic cascade process [9, 10]. In such a cascade, high energy neutrons extending up to hundreds of MeV, charged and neutral pions etc. are generated in less than a microsecond. Pions immediately decay to neutral and charged muons. Neutral pions decay decays to high energy gamma rays leading to electromagnetic cascade whereas charged muons lose its energy by ionization, weakly and may contribute to dose equivalent outside shielding of high energy proton accelerators operating in the GeV level. The prompt neutron emission from proton and heavy ions are tabulated in literature [24].

The struck nucleus/structural material will be left in a highly excited state and will decay with the emission of beta, gamma or alpha and hence the induced activity issues are of several magnitudes higher than that of an electron accelerator. Induced activity in air, cooling water, accelerator components may limit access to machine areas immediately after putting off the accelerator [21]. At high energy, high power proton accelerators used for ADSS and SNS applications, induced activity issues needs special attention. The likely radiological safety issues of accelerator driven system are described in literature [25,26].

CHALLENGES IN RADIATION PROTECTION AT ACCELERATOR FACILITIES

The challenges faced by radiation protection professionals in accelerator facilities are many. The challenges are mainly due to the characteristic radiation environment prevailing in such facilities. Important among them are the following.

— Dynamic nature of the radiation level due to change in beam loss

Radiation level in an accelerator facility depends on the beam loss scenario at various stages of acceleration process. Usually the shield design is carried out based on assumed beam loss scenario. Actual beam loss scenario may be different and may vary depending on the system performance. Realistic beam loss scenario shall be generated and a guideline needs to be evolved.

— Lack of systematic data on source term

Experimental source term data is not available at high energies, beyond few hundreds of MeV. Very often extrapolation of existing data at a lower energy or simulated data is used for the shield evaluation in the absence of experimental source term data. Some of the authors have attempted to generate source term based on experiments and simulations for high energy electron accelerators [27-29]. More experimental data is required to be generated and a comparison with simulation is required to validate them.

— Detection and measurement of high and low energy radiation

Area radiation monitors and survey instruments are not that easily available commercially for monitoring of the radiation level in high energy radiation fields as encountered in high energy accelerators. The energy response of most of the available monitors is well known up to few MeV only. In a high energy radiation field, these monitors may give wrong reading. Similarly, in the low energy regime, from few tens of keV down to few keV, monitoring and assessing dose is a challenge due to lack of proper active detection systems. Dose rates due to intense low energy synchrotron radiation in the x-ray region, down to few keV are very high and highly collimated. This complicates the issue further. Recognizing these issues, some development in extending the energy response of ion chamber-based survey meters to low energies up to few keV as well as extending the high energy response of neutron rem-meters has taken place in the recent past.

— Under estimation of personal and ambient dose equivalent

Personal dose equivalent recorded by dosimeters worn by workers may underestimate the dose due to build up effect on account of electromagnetic or hadronic cascade generation. Deep within the body the dose may be higher by several factors than that recorded by the dosimeters worn on the surface [17]. Underestimation is also possible due to the directionality of the radiation as the dosimeter may miss the radiation and show a safe reading whereas the exposed part of the body may be different than the dosimeter location. Underestimation is also possible due to highly anisotropic radiation like in bremsstrahlung and synchrotron radiation where the active volume of the detector / survey meter may not be exposed fully while carrying out a measurement whereas due to scattering effect (which may happen when incident on an absorber / human body) detector response improves due to the increased scattered beam size.

— Radiofrequency interference

Various types of RF devices like Klystrons, RF amplifiers, RF cavities etc. are employed in accelerators where acceleration is achieved with the help of RF electric field across a cavity. Leakage RF field is likely to interfere with radiation monitoring instruments and give erroneous readings. Use of RF shielded instruments or ensuring no leakage RF field is very essential while carrying out survey for x- rays near RF devices.

— Enforcing regulatory recommendations and radiation protection procedures

Due to the non-routine nature of the work of the researchers, enforcing regulatory recommendations and radiation protection procedures becomes a difficult task. Hence broad guidelines listing procedures to be followed in research accelerator facilities needs to be evolved, which form a basis for implementing them by regulators and radiation protection professionals. Radiation Safety Officer (RSO) should be empowered in recommending appropriate action in case of any violation of radiation safety procedures.

CONCLUSIONS

Accelerators in terms of energy, intensity and technology are growing at a rapid pace, which is driven by the need of industry, research & development in basic and applied science, medicine, agriculture and in many other fields. All these are going to have enormous benefit to the society and environment. Due to the technological advancement in the field of accelerators, many challenges are being faced by radiation protection professionals, which need to be addressed. There are areas like development of area monitors and survey meters suitable for monitoring high and low energy radiation, pulsed radiation and mixed field, where a serious thought is to be given. Substantial research is required to address these issues. Due to the uncertainties in dose estimation prevailing in these peculiar radiation environments, one has to give importance to engineered, redundant radiation safety systems like various interlocks, shielding (with safety margin), zoning, access control and strict adherence to training of personnel and operational procedures. Also, efforts shall be made in standardizing radiation safety systems for accelerator facilities and evolving a policy for ensuring their effectiveness.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 5

M. R. Gaunt

United Kingdom

1. Exposure of Industrial Radiography Operators: A Case Study.Simo et al.

The National Radiation Protection Agency (NRPA) of Cameroon started to provide a dose monitoring service in 2011, which had previously been provided from outside the country. As part of its routine dose monitoring of workers in 2012 the service identified unusual exposures associated with operators working for an NDT company. Monthly doses to three individuals were reported as 13.46mSv, 10.38mSv and 6.8mSv and were investigated.

Gamma radiography had been undertaken in difficult conditions on distillation columns at heights of 6 meters and 1 meter at night. The investigation into the exposures revealed some shortfalls in the use of equipment and working procedures.

Recommendations included the need to review the management system in terms of organisation and the provision of appropriate equipment that is properly maintained. Radiographers should be provided with and know how to use: dose rate meters, personal dosimeters and alarming detectors.

Site radiography is often undertaken in adverse conditions and many of the shortfalls identified are common in such events.

In addition, results of a questionnaire sent to radiography companies identified that such work was in some cases being undertaken without the presence of a radiation protection officer.

2. The occupational radiation protection of the training reactor of Budapest University of Technology. Lajtos et al.

The Institute of Nuclear Techniques at Budapest University consists of two units: The Department of Nuclear Techniques is responsible for educational tasks and the Department of Nuclear Energy operates the nuclear training reactor Pool type reactor of 100kW maximum power). The main training task is to educate undergraduate, graduate and PhD students in the field of nuclear engineering, nuclear and reactor physics and radiation protection. The reactor is visited by 1500 students a year from secondary schools and universities.

The facility provides operational controls and the provision of dosimetry using TLDs supplemented by electronic dosemeters. Film badges were used until 2013, but the transition to TLDs enables lower doses to be measured.

The management of the Institute of Nuclear Techniques consider education and training in radiation protection as one of the most important issues and students become familiar with both the legal and practical aspects of radiation protection and design issues associated with the workplaces from a radiation safety perspective.

The training in radiation protection is a fundamental contributor to the low annual exposure levels observed at the facility.

3. Challenges of occupational radiation protection at high power laser facilities Olsovcova

The rapid development of high power laser facilities in recent years has required consideration of protection from ionising radiation from X-rays and high energy charged particles. The paper summarises the methods for the design and implementation of an occupational radiation protection programme.

The PALS research centre in Prague operates two laser systems: a 3 TW iodine laser and a 25 TW Titanium sapphire laser system.

Whilst the general principles of radiation protection are applicable for designing and operating such laser facilities there are certain unique challenges. Existing laser facilities were not designed with ionising radiation in mind thus the shielding capabilities of the existing civil structure needs to be assessed and the effectiveness of the shielding confirmed. Use of such lasers also results in the need for a large number of penetrations to accommodate the various services required.

In addition, each beam line requires appropriate beam dumps. Because of the nature of the work neither the source term nor the exact geometry of the beam line is known requiring the beam dump design to be variable.

Challenges are also presented in personnel and workplace monitoring as commercially available instruments are designed for the detection of continuous fields whereas the laser facilities produce very short pulses with a low repetition rate.

Measurements performed to date indicate that the use of passive dosimetry is the most suitable.

Designing a functional occupational radiation protection programme is a complex procedure and requires the co-operation of specialists in different fields. The development of a healthy safety culture at all levels is a key component to the safety of the facility.

4. Statistical analysis of the doses received by the aircrew and medical personnel: Comparison and trends Carinou et al.

The paper analyses and compares doses to aircrew and medical personnel in Greece. The Greek Atomic Energy Commission (EEAE) is the national competent authority radiation protection, radiological and nuclear safety. The EEAE has developed and operates an integrated central information system, the National Radiation Protection Database, where information on occupationally exposed workers is kept. In Greece, the majority of exposed workers are in the medical sector. Aircrew exposures are evaluated using computer software.

Analysis of dose distributions mean annual doses and trends provide valuable evaluation criteria for the optimisation of the radiation protection programme in Greece. The analysis was performed over a three-year period 2011 to 2013 and contained all doses greater than or equal to 0.1mSv.

In 2011 the collective dose for aircrew was half that of the medical sector, but in 2012 and 2013 the collective doses were of the same order. In 2011 the mean annual dose in the medical sector was almost double the value see for aircrew (1.36mSv against 0.77mSv), but in the following years mean annual doses of medical personnel were slightly higher.

Examining the dose ranges showed no aircrew exposures above 6mSv, but the numbers of personnel in the dose range 1 to 6mSv is higher for aircrew. No difference was observed in the mean annual doses between male and female aircrew, but men were more exposed than women in the medical sector.

The study looked more closely at the distribution of doses between the two sexes. The shape of the distribution for the number of workers in the medical profession was broadly similar, whilst the distribution among aircrew is very different. For male aircrew the maximum distribution is between 30 to 49 years, whilst for women the maximum is seen between 20 to 29 years. This is a reflection of the nature of the roles and the required experience.

The national central register is seen as a powerful tool for continuously monitoring and evaluating the national radiation protection programme.

5. Radiation protection during the neutron guide modification project at the Opal research reactor (Australia) Maharaj

In early 2012 the Australian Nuclear Science and Technology Organization (ANSTO) commenced a project to modify the Cold Neutron Guide at its 20MW OPAL research reactor. Radiological exposures were anticipated to staff involved, but were justified on the basis of benefits to the Australian public, industry and the research community.

Dose assessments were conducted to create a dose estimate for the project and a radiation protection plan was developed.

Routine task and individual monitoring were undertaken and specific radiation safety training delivered. The radiation protection arrangements were reviewed daily and feedback given to the project team.

There was some variation in the estimated gamma dose rates and actual measured maximum values. However, through the implementation of the controls and ongoing monitoring of dose trends against dose budgets individual and collective doses were below the estimated doses.

Slight variation was noted between electronic dosimetry and TLD records, with the TLD recording doses recording approximately 20% higher than the electronic dosimetry. This was attributed to factors such as the response of the types of dosimetry and how they were worn in relation to each other.

The benefits of detailed planning and involvement of all departments associated with the work was an essential part of the success of the project. The continuous monitoring of daily and collective dose for staff and effectively applying the planned radiation protection arrangements allowed advise on control of exposures to maintain collective and individual doses to be well within the dose targets and constraints set for the project.

CHAIRS' SUMMARY OF TOPICAL SESSION 5

Occupational radiation protection in industrial radiography is relatively mature with a systematic approach involving Radiation Protection Officers, training and qualification following IAEA recommendations. But there are occasional accidents and a need for improvement in harmonization (and recognition) of training, equipment, and communications.

In the keynote lecture, Richard van Sonsbeek from Applus Roentgen Technische Dienst (Roentgen Technical Services) of the Netherlands, in his role as the Chairman of the Industrial Radiography Working Group of the Information System on Occupational Exposure in Medicine, Industry, and Research (ISEMIR), discussed the current status of radiation protection in industrial radiography as determined via a survey that was conducted by the Working Group Industrial Radiography (WGIR) of the ISEMIR project of the IAEA. The WGIR concluded that considerable improvement is needed in the area of occupational radiation protection in industrial radiography, especially in the area of implementation of optimization of protection. Consequently, the WGIR developed two tools, an international database and a road map, which can be used to assist end-users in improving their radiation protection programs. Various recommendations were given to IAEA for further action to include: development of an internationally recognized training standard for safety in industrial radiography operations, encourage adoption of the equipment standard ISO 3999 as a means of international certification, and determine the circumstances and reasons why radiographers do not always use survey meters in order to avoid accidents. The WGIR of the ISEMIR project could play a significant role in the implementation of these actions. The main challenge is achieving broader involvement form the non-destructive testing industry.

Aayda Al Shehhi, a physicist from the Federal Authority for Nuclear Regulation (FANR) of the United Arab Emirates, provided a regulator's perspective on issues in occupational radiation protection in industrial radiography. FANR is still in the process of developing an occupational radiation protection infrastructure to manage oversight of service providers that cover dosimetry, calibration, certification, and training services in radiation safety. FANR has been active in outreach to provide a culture of communication with licensees, gain mutual trust, and enhance the safety culture. Operators, as well as the regulators, face challenges with regard to improving occupational radiation protection in industrial radiography. These challenges include: industrial radiographers receiving excessive doses, blaming employer, and lack of training. Other issues include a lack of positive safety culture and communication problems because the expatriate industrial radiographers do not speak Arabic or English.

Etienne Martin from the French Non-Destructive Testing Confederation in France (COFREND) discussed controlling the risk due to the use of gamma sources for non-destructive testing and first feedback from the deployment of replacement non-destructive testing techniques. In an effort to reduce the risk associated with industrial radiography, the French Nuclear Safety Authority began to work with industrial radiography companies to develop and optimize the best practices during radiographic inspections, and evaluate replacement techniques to radiographic testing. Utilities undertook a global initiative to reduce the number of gamma exposures associated with non-destructive testing within the last five years (e.g., replacement, limitation of exposures), thereby, reducing the risks. Industrial radiography will continue to have an important role in non-destructive testing, because there are situations where radiography was found to be the most appropriate and most efficient type of non-destructive testing technique. For these cases, the use of less powerful x-rays and gamma-ray sources and the implementation of good practices by the operators can highly reduce the risks of radiation exposure.

Charlotte Kaps from the German Society for Non-Destructive Testing provided an overview of the training and education requirements for occupational radiation protection in industrial radiography. Every Radiation Protection Officer is liable for his in-plant authority; however, this is found to be challenging for on-site industrial radiography. In Germany, radiation protection training is required by law; training is also addressed in international standards. Training in combination with work experience and up-to-date courses is one step towards safe and secure handling of sources and radiation protection. Germany has different training requirements depending on the job position (Radiation Protection Officer for overall direction versus on-site Radiation Protection Officer) and the technique (gamma radiography versus x-ray radiography). Knowledge in radiation protection can be proved by written exams during a course, but work experience is much more difficult to ensure. An option to address this challenge is the certification of non-destructive personnel. It is the responsibility of the employer to ensure that trainees will be able to apply their knowledge in practice, and work experience in radiation protection and industrial non-destructive testing experience for radiographic testing.

Haridas Gopalakrishnan from the Department of Atomic Energy in India discussed the challenges of occupational radiation protection at accelerator facilities. Accelerators in terms energy, intensity and technology are growing at a rapid pace, which is driven by the need of industry, research & development in basic and applied science, medicine, agriculture and in many other fields. Due to the technological advancement in the field of accelerators, there are many challenges faced by radiation protection professionals, which are mainly due to the characteristic radiation environment prevailing in such facilities.

Important among them are:

- Dynamic nature of the radiation level due to change in beam loss scenario;
- Lack of systematic data on source term;
- Detection and measurement of high and low energy radiation;
- Underestimation of personal and ambient dose equivalent;
- Radio-Frequency (RF) interference;
- Enforcing regulatory recommendations and radiation protection procedures

There are areas, such as development of area monitors and survey meters suitable for monitoring high and low energy radiation, pulsed radiation and mixed field that need to be undertaken by the manufacturers. Substantial research is required to address these issues. Due to the uncertainties in dose estimation prevailing in these peculiar radiation environments, one has to give importance to engineered, redundant radiation safety systems like various interlocks, shielding (with safety margin), zoning, access control and strict adherence to training of personnel and operational procedures. Also, efforts shall be made in standardizing radiation safety systems for accelerator facilities and evolving a policy for ensuring their effectiveness.

TOPICAL SESSION 6:

OCCUPATIONAL RADIATION PROTECTION IN EMERGENCIES AND EXISTING (POST-ACCIDENT) EXPOSURE SITUATIONS

Chairpersons: A. Gonzalez, Argentina and V. Kutkov, Russian Federation

LESSONS LEARNED: RADIATION PROTECTION FOR EMERGENCY RESPONSE AND REMEDIATION / DECONTAMINATION WORK INVOLVED IN TEPCO FUKUSHIMA DAIICHI NPP ACCIDENT

S. Yasui

Ministry of Health, Labour and Welfare, Japan

Abstract

The paper describes problems that occurred during emergency work at TEPCO Fukushima Daiichi NPP in 2011 and extracted lessons learned from the experiences from radiation protection and provided guidance regarding preparedness for a similar accident. The paper also provides information regarding persons responsible for legislation regarding radiation protection in an existing exposure situation.

INTRODUCTION

In response to the Fukushima Daiichi Nuclear Power Plant (NPP) accident that resulted from the East Japan Earthquake on March 11, 2011, the Tokyo Electric Power Company (TEPCO) undertook emergency work to which an emergency dose limit applied. The Japanese government increased the emergency dose limit from 100 mSv to 250 mSv exclusively for the emergency work performed at the affected NPP from March 14 to December 16, 2011.

During the emergency work, the Japanese government experienced various problems in the management, control and reduction of radiation exposure, and medical and health care management for emergency workers. For the proper implementation of radiation protection and health care management, the Ministry of Health, Labour and Welfare (MHLW) issued a series of compulsory directives and administrative guidance to TEPCO.

Furthermore, the accident released a large amount of radioactive material. To rehabilitate the contaminated areas, the government of Japan decided to carry out decontamination work (e.g., clean-up of buildings and remediation of soil and vegetation) and to manage the waste resulting from the decontamination and unmarketable contaminated goods. To prevent radiological hazards, the government needed to provide sufficient radiation protection for the decontamination workers.

The paper aims to describe the lessons learned from the experience of those responsible for radiological protection and to provide guidance regarding preparedness for a similar accident. The paper also aims to provide useful information as a reference to lawmakers and government officials responsible for the legislation regarding radiological protection in an “existing exposure situation.”

METHODOLOGY

In August 10, 2012, the MHLW summarized lessons learned from the TEPCO Fukushima Daiichi NPP and issued a notification document regarding emergency preparations to all operators of nuclear facilities [1]. The MHLW established new regulation and amended the existing general regulation for radiation protection of decontamination workers, based on the report from expert meetings. As a summary of relevant information, the MHLW published a booklet which explains actions taken by the MHLW in November 2013. Factual information described in the paper was based on the summary, the notification and the reports, unless otherwise specified in the references. Given limitations on the size of the presentation, the paper could not describe detailed actions taken by the MHLW and TEPCO, actions which are described in the MHLW booklet.

PROBLEMS OCCURRED IN RADIATION PROTECTION AND HEALTH CARE MANAGEMENT

— Trend of workers dose during the emergency stage and current status of the affected plant

During the emergency period from March to November 2011, the maximum and average monthly doses were 21.51 mSv and 4.69 mSv, respectively. The average number of monthly workers who were exposed to more than 5 mSv was 1,236 (Figure 1). From December 2011 to August 2014, the maximum and average monthly doses decreased to 1.40 mSv and 1.04 mSv. The average number of monthly workers who were exposed to more than 5 mSv was 245 (see Figure 2) [2].

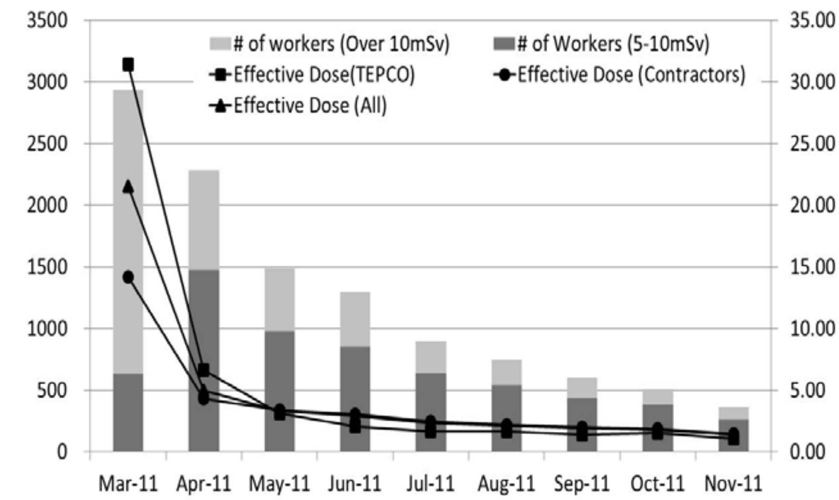

FIG.1. Trend of radiation exposure of workers at the Fukushima Daiichi NPP (March-November 2011)

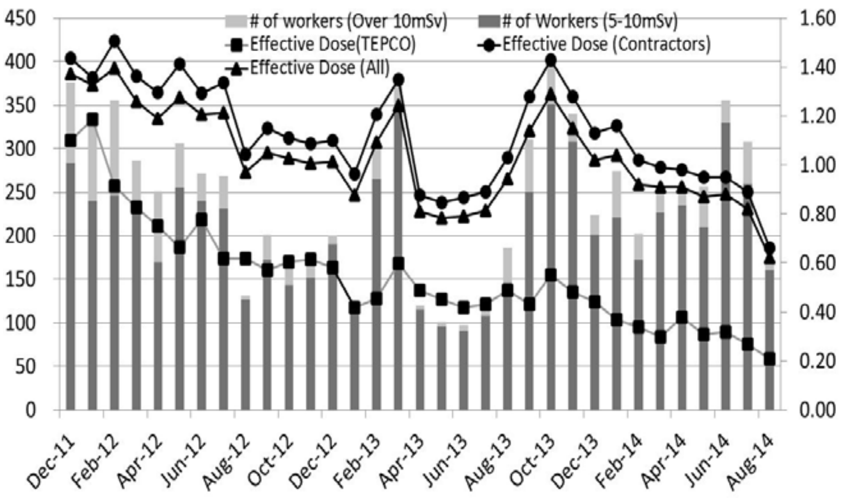

FIG.2. Trend of Radiation Exposure of Workers at Fukushima Daiichi NPP (December 2011-August 2014

— Radiation protection

During the emergency work, the MHLW observed the following radiation protection problems [3,4]:

- *Inappropriate Exposure Monitoring because of Shortage of Personal Dosimeters:* The tsunami damaged a large number of electronic personal alarm dosimeters (PADs). The surviving dosimeters could not be recharged because of the electrical blackout at the site. The number of usable dosimeters decreased to approximately 320 on March 15, 2011, whereas the number of emergency workers increased progressively. Under these circumstances, from March 15 to March 31, 2011, TEPCO could not supply PADs to all workers, but only one dosimeter for each work group and assign the monitored exposure dose as the common dose to the group.
- *Inappropriate Dosimeter Circulation Management and Exposure Control:* Given the breakdown of the electronic exposure management system, TEPCO implemented paper-based dosimeter circulation management at the plant until April 4 (until June 8 in the support facility known as J-Village). However, certain workers wrote down only their family names, writing in illegible characters. As a result, TEPCO faced the difficulty of conducting name-based aggregation of doses and a calculation of accumulated individual doses.
- *Workers Who Were out of Contact:* During the process of name-based aggregation, on June 20, 2011, it was revealed that several workers whose identities could not be confirmed, appeared on the circular list. The number of workers who were out of the rosters reached 174 at maximum. (MHLW or TEPCO?).
- *Internal Exposure Monitoring:* Because of the accident, TEPCO could not operate the whole body counters (WBCs) that were located in the affected plant, because of the increase in the background radiation level. In response, on March 22, 2011, TEPCO started to operate two vehicle-mounted WBCs. However, the capacity of the WBCs was insufficient to cover all of the emergency workers.
- *Exceeding Emergency Dose Limits:* The exposure doses of six emergency workers had exceeded the emergency dose limit (250 mSv), which the Japanese government increased from 100 mSv on March 14, 2011.

- *Internal Exposure That Resulted From the Inappropriate Use of Protective Masks:* Internal exposures beyond record levels were repeatedly found until September, which was six months after the accident.
- *Protection against Beta-Ray Exposure From Contaminated Water:* During the emergency work, several incidents of beta-ray exposure occurred in relation to contaminated water, such that workers received beta-ray exposure on their feet after they stepped into 30 cm deep contaminated water while wearing half boots to install electrical cables in a reactor building basement.
- *Worker Training:* From the time of the accident until May 2011, TEPCO and the primary contractors conducted training for newcomers for only 30 min.

— Medical and health care management [6]

The following observations were noted during the emergency health care management:

- *Implementation of Emergency Medical Examinations:* On March 16, 2011, the MHLW issued compulsory instruction to TEPCO to implement special medical examinations for screening of acute radiation syndrome or local radiation injuries every month. The implementation rate from March to September rose gradually, but remained low: 31.3%, 59.3%, 61.7%, 63.6%, 61.9%, 70.7% and 70.6%, respectively.
- *Establishment of On-Site Medical Care Systems:* Although 2,000 to 3,000 emergency workers per day were consecutively engaged in emergency work in the affected plant, TEPCO could maintain the presence of physicians and medical staff only during the daytime for a few days in each week during the early stages of the accident.
- *Patient Transportation from the Affected Plant:* 3 of the 5 initial medical facilities were located in the evacuation zone and a hospital was located in the indoor evacuation zone. At the other hospital, supply of water and electricity were lost or malfunctioned. On March 14, 2011, Fukushima Medical University (FMU) became prepared to accept patients. However, the transport from the affected plant took 3-4 hours.
- *Prevention of Heat Illness:* The MHLW was concerned that heat illness could develop if emergency workers spent long hours under the blazing sun while wearing full-face respiratory masks and HAZMAT garments.
- *Lodging and Food:* During the emergency situation, approximately 400 workers had to sleep on the floor of the Seismic Isolation Building of the affected plant or gymnasium of the Fukushima-Daiichi NPP, 13 km from the affected plant. For the prevention of internal exposure, TEPCO restricted the food supply to workers to boil-in-bag foods.

ESTABLISHMENT OF NEW REGULATIONS FOR RADIOLOGICAL PROTECTION FOR DECONTAMINATION / REMEDIATION WORK

— Decontamination, recovery and reconstruction works

Existing government regulations assumed that the radiation sources were controlled and collected in indoor restricted areas referred to as “planned exposure situations.” The government had not considered the possibility of a situation where radiation sources were scattered, and workers would have to deal with radioactive material outdoors (referred to as an “existing exposure situation”). ICRP Publication 103 states that exposure involving long-term rehabilitation of the contaminated areas should be treated as a part of planned exposure, although it does not provide details regarding exposure management. ICRP Publication 111, which mainly addresses an existing exposure situation, gives a few recommendations regarding occupational exposure.

Given the insufficient international recommendations, the MHLW decided to establish new regulations on occupational radiological protection in an existing exposure situation by using the protection in a planned situation as a reference. During its deliberation, the MHLW employed the following three principles [7]:

- Ensure that the level of protection is equivalent to or greater than the level in a planned situation and adhere to existing regulations in a planned situation.
- Be practical and function smoothly in the situation around the affected plant, which is limited by restricted infrastructure, supplies and resources for the decontamination work.
- Be consistent with the radiological protection for the inhabitants around the work sites to avoid anxiogenic effects because decontamination projects have to be carried out in daily living areas, in full view by inhabitants, unlike in the case of works done in radiation-controlled areas.

— Disposal of contaminated water and waste

Disposal of contaminated materials removed by decontamination requires workers to engage in work primarily conducted in indoor radiation-controlled areas. The MHLW therefore applied the existing general regulation for radiation protection to disposal workers. However, those regulations were difficult to apply to the disposal of removed decontaminated- materials because this involved handling of huge amounts of materials, required large-scale facilities, involved fragmentation processes and landfill operations, and included operations that had to be conducted in high-ambient-dose-rate environments. Thus, the MHLW decided to amend the general regulation and establish new prescribed radiation protections for workers engaged in disposal of material removed as part of the decontamination work [8].

DISCUSSION

— Lessons learned in radiation protection and healthcare management

In August 10, 2012, the MHLW issued a notice to urge nuclear operators to perform the necessary preparation to avoid similar problems with exposure management in the case of an accident. The major points of the document are as follows:

Sufficient measures and systematic preparation for radiological management should be ensured, including the following: a) Assistance from the power company's corporate office or off-site support facilities outside the evacuation area is indispensable; b) Primary contractors must independently implement exposure management operations for the employees of their subcontractors; c) NPP operators should compile an operation manual, stockpile personal protective equipment and personal alarm dosimeters (PADs), and have ready emergency systems and whole body counters (WBCs).

To reduce the exposure dose, the following lessons should be shared: (a) to prevent internal exposure, it is necessary to monitor the radioactive concentration of the indoor air of the workplace during an emergency, to stockpile and use appropriate respiratory protection and train newcomers how to use the protective means, fit and fit-test the respirators; (b) to prevent unnecessary beta-ray exposure, wear liquid-proof garments that should be mandatory when workers handle contaminated water; (c) to reduce external exposure, it is indispensable to develop well-prepared work plans prior to do the work and to monitor the ambient dose rate in the work area to develop proper working procedures; (d) the timely deployment of remote-controlled vehicles and the utilization of tungsten shielding vests can contribute to exposure reduction.

The proper management and implementation of medical and health care management would require the following: (a) The government needs to assist in dispatching medical staff to the affected plants; (b) Nuclear facility operators, medical facilities and fire departments should make an agreement to clarify the division of the roles played prior to the accident and should conduct emergency drills periodically with the full attendance of related personnel to identify and resolve problems; (c) Operators need to develop a support base at a safe distance from the plant and to develop shift lodgings in case of emergency; (d) Operators need to come to an agreement to share food stocks among closely located nuclear plants and prepare cooking equipment that can be used in case of blackout, in order to provide warm foods and drinks to as many workers as possible; (e) It is necessary to conduct long-term follow-up for emergency workers, including the health care system, medical examinations and mental health consultations.

— Problems to be resolved in establishing new regulation in existing exposure situations

The MHLW faced difficulties in determining how radiation protection systems intended for planned exposure situations should be applied to the existing exposure situation. The MHLW did not have a sufficient scientific basis and sufficient time to establish new protection systems for the existing exposure situation. Consequently, the MHLW had no choice but to consider the existing radiation protection systems and make every effort to adapt them to the current situation. To establish new regulation systems for the existing exposure situation, further research and development concerning the following issues is warranted:

- The relationship between the radioactive concentrations of materials handled and the risk of internal exposure: The amended regulation requires the use of appropriate personal protective garments and masks, as well as internal exposure monitoring in accordance with exposure estimation, based on the radioactive concentration and multiplied by the density of dust at working sites. However, there were no scientific experimental data available to prove the validity of this estimates.
- The relationship between the radioactive concentration of the soil and the workers' surface contamination level: Experimental and empirical studies of this relationship would make it possible to establish a standard for when to require contamination screening. Further development of this subject is warranted.

In the case of disposal of contaminated water and waste, two issues became controversial. The first one was the balance between the competing goals of radiation protection and ensuring working efficiency, which is necessary for the smooth disposal of 30 million tons of contaminated materials. The issue surfaced in the application of radiation protection to landfill disposal of removed soil. The other issue was the application of the regulation to conventional waste disposal facilities, which were not originally designed to accept radioactive substances.

CONCLUSIONS

The problems that occurred in the accident would not have occurred or would have remained minor if TEPCO had ensured sufficient and systematic preparation for large scale accidents. Based on the lessons, international guidance documents were warranted to be necessary for the governments and NPP operators to perform necessary preparation for radiation protection for emergency workers.

The areas of the existing exposure situation overlap the areas of planned exposure situation. Thus, a demarcation line between the application of existing regulations and new regulations has to be defined and operated in accordance with the situations after accidents. It is desirable that government officials, responsible for radiation protection, develop international guidance documents that provide useful information based on the Japanese case.

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COMPARISON OF OCCUPATIONAL RADIATION PROTECTION FOLLOWING THE CHERNOBYL AND FUKUSHIMA ACCIDENTS

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Abstract

Lessons learned from the emergency response and recovery operations undertaken after the major nuclear accidents at Chernobyl NPP and at Fukushima Daiichi NPP are discussed. General information concerning radiation situation on-site is considered as the starting point for comparison of the applied actions and strategies. The similarity in emergency regulation and distinction in management are demonstrated. Comparison of average doses and dose distribution for different cohorts of emergency workers and recovery operation workers differ approximately by a factor of 10.

BACKGROUND

Major nuclear accidents at the Chernobyl NPP and at the Fukushima Daiichi NPP (Fukushima-1) are separated by a quarter of century. International nuclear society and national competent bodies applied many efforts to improve the emergency preparedness and response systems during this period of time. When comparing the actions directed on occupational protection of emergency workers (EWs) and recovery operation workers (ROWs), following these accidents, one should take into account different characteristics of the events, regulations, applied emergency response, recovery strategies and other aspects related to radiation safety.

Bibliographies used in this paper include formal governmental reports, regulatory documents, scientific studies, judgments of international organizations as well personal communications to individuals involved in these dramatic events [1-9]. This paper emphasizes on lessons learned from the response on-sites. EWs deal with the obligatory urgent measures aimed at preventing catastrophic development of the accident and localization of uncontrollable radioactive source. This category of EWs had to work in the most hazardous radiation conditions and may be exposed above dose limits.

The comparison of Chernobyl and Fukushima-1 is aimed at clarifying similar crucial issues of emergency response and safety in those accidents rather than to judge when applied occupation protection was better or worse.

BRIEF DESCRIPTION OF EVENTS AND RESPONSE

— Source term and radiation situation on-sites

Chernobyl. Accident occurred on 26 April 1986 during a low power engineering test of the Unit 4. Successive steam explosions completely destroyed the reactor and damaged the reactor building. Short circuits and fires appeared soon after explosions. Radioactive release continued over 10 days due to following reasons: explosions (both, fine-dispersed fuel and heavy radionuclides were released from the fuel), graphite burning (6 days) and fuel overheating as a result of radioactive decay (4 days). Total release amounted more than 12,000 PBq, including 6,500 PBq of inert gases, 1,800 PBq of ^{131}I, 85 PBq of ^{137}Cs. Spatial balance of the released nuclear fuel was as follows: 9% - NPP site, 44% - 80-km zone, 44% - the rest of the USSR, 3% - outside the USSR. The NPP site area (around 1 km2) was mainly contaminated by dispersed nuclear fuel immediately after the explosions. Radionuclides ^{95}Zr, ^{95}Nb, ^{103}Ru, ^{141}Ce, ^{144}Ce created the main contribution (above 10% of each) to the total contamination on-site during the first 100 days after the accident. ^{134}Cs and ^{137}Cs contributed only (1–3) % at that time. Average air kerma rate was estimated to 400 mGy h^{-1} in the first day after the accident, 200 mGy h^{-1} ten days later and 40 mGy h-1 one hundred days later [8].

Fukushima-1. Accident occurred on 11 March 2011 owing to tsunami triggered by a severe offshore earthquake. Flooding of the power plant and damage to the equipment resulted in an extended blackout, loss of the core cooling, fuel melting, hydrogen explosions and releases of radioactivity into environment. Assessments of the release were estimated by various organizations and they corresponded to each other. For instance, Nuclear and Industrial Safety Agency has reported the total release of 370 PBq, including 130 PBq of ^{131}I and 6 PBq of ^{137}Cs. So, on-site contamination was mainly due to the deposition of 131I and 137Cs. Taking into account data of exposure dose rates measured on-site, average air kerma rate was estimated around (0.1–0.2) mGy h^{-1} during the first five days after the accident. Transient sudden changes in exposure rates were observed shortly after hydrogen explosions and opening the vents of the containment vessel.

Comparison. General comparable assessment of Chernobyl and Fukushima accidents is based on the comparison of the iodine and cesium releases. Those releases for Fukushima Daiichi were approximately one-tenth of the Chernobyl amounts. However, the difference becomes more significant if one takes into account on-site radiation situations. Situation at the Chernobyl NPP was three orders of magnitude more severe. Exposure rates in a range of hundreds – thousands of mGy h^{-1} at the working places created real threat for the first responders at the Chernobyl NPP.

— Cohorts of workers engaged in the emergency response and actions undertaken

Chernobyl. Formally, both EWs and ROWs were engaged in the termination of the Chernobyl accident and in mitigation of its consequences in the affected areas (in the1986-1990 span) as Participants (named as Liquidators). The duration of emergency exposure situation is assumed to be 7 months (26 April – 30 November 1986) in this presentation. Conditionally, 3 phases may be delineated at that period: urgent, early and transition to recovery phases. Number of EWs and ROWs is given in Table 1.

Urgent actions immediately after explosions included fire control, saving life, restore power and water supply of the cooling system, lube swap, examination of equipment, radiation reconnaissance, vent operations etc. Total number of EWs and witnesses of accident in the industrial site during the first 8 hours was 1057, including 176 members of operation personnel of Units 1–4, 258 builders of Unit 5, 6, 24 firemen and 23 security guards to be at the scene at the moment of the accident.

Early actions were pointed towards prevention of the development of catastrophic conditions. The measurements of neutron flux were taken as an evidence of nuclear chain reaction. This wrong assumption became the starting point in the set of early countermeasures directed towards nuclear safety. Uncertainties and overestimation of the threats led to controversial decisions to cover the reactor with materials by helicopters, to build concrete slab (30m*x*30m*x*2.5m) with the cooling system under the reactor, to supply liquid nitrogen into under-reactor premises. The other decisions and actions, such as water pumping out of the bubbler-basin, dust catching, radiation monitoring and fire control on May 23 can be regarded as helpful.

TABLE 1. COHORTS OF EMERGENCY WORKERS AND RECOVERY OPERATION WORKERS AND AVERAGE DOSES IN 1986 [4]

No	Cohort	Number, thousands	Average dose, mSv	Dates
1	First responders	1	550	April, 26
2	Early response teams	35	115	27.04–20.05
2.1	Military	13		
2.2	Civil	22		
3	Recovery operation workers	89	82	21.05–30.11
3.1	Military	49	95	
3.2	Civil	40	70	
Total		125	95	134

Recovery strategy was relayed to the highest national political and governmental level on May 29. Large-scale measures, including restoration of the NPP, building of the shelter, returning the evacuated population and so on required to increase the size of the workforce. Adopted decree ordered to call up reservists for 6 months to accelerate decontamination operations in the Chernobyl NPP zone.

Fukusima-1. Urgent actions were directed on the restoration of emergency electrical power, core cooling and decreasing the containment pressure below the design level. Unfortunately, attempts to restore control over the reactors of Units 1-3 and spent-fuel pool of Unit 4 from, undertaken from 11 to 15 March were unsuccessful. Personnel of the NPP were evacuated on 15th March, except of 50 EWs who targeted their efforts on problems of Units 5 and 6.

Measures taken in the urgent phase continued at the early stage. On-site decontamination near the destroyed buildings and waste management started. Self-Defence Force personnel and others were engaged in these works. In March 2011, total number of early EWs was about 4 thousand, including 2,300 of contractors.

Melted fuel within the reactors, spent fuel in pool, contamination of containments, processing large volume of contaminated water, debris, soil and secondary wastes became the main issues of the recovery actions. TEPCO has established a road map that describes procedures for the on-site clean-up and liquid waste management [7].

Comparison. Both, workers and people who had no radiation experience were involved in actions on-site after the accidents. This fact led to economic, social and psychological consequences. Emergency response undertaken and applied recovery strategies were different in Chernobyl and Fikushima-1 cases. EWs consisted of independent groups and focused on certain tasks within their own management and dose control.

APPLIED SYSTEM OF OCCUPATIONAL RADIATION PROTECTION

— Emergency regulation

Chernobyl. General approach to a problem of radiation protection of rescuers and EWs during the Chernobyl accident and present guidance does not differ. Basic regulatory requirements on emergency response included the following:

- Overexposure of EWs above the dose limits may be justified for the purpose of saving life, averting a large-scale public overexposure, and preventing the development of catastrophic conditions;
- Elevated planned exposure (EPE) shall be below the double of the annual dose limit for single undertaken action and fivefold of the dose limit for the entire emergency period (i.e., 100 and 250 mSv); and
- Written permission of administration and personal consent of EW to EPE is required.

After the accident, “temporary dose limit” of 250 mSv was adopted for EPE. However temporary limit for military participants was 500 mSv till 21 May 1986.

Fukushima-1 The emergency dose limit was set at 100 mSv year^{-1} before the accident. On March 14, the Ministry of Health, Labour and Welfare raised the allowable dose limit for emergency workers to 250 mSv. Comprehensive organizational scheme of the disaster response was established.

Comparison. The use of terms “temporary dose limit” and “emergency dose limit” differ from the guidance values recommended IAEA. In addition to the terminology differences, limits applied to both EWs and ROWs and not only for rescuers and EWs involved in specific tasks (4.15 and Table IV-2 General Safety Requirements Part 3).

— Management

Chernobyl. Shortcomings in the administrative response immediately after the accident were as follows: “Dose order form” and procedure for “Elevated Planned Dose Permission” did not apply to all organizations; ignoring the hazard of overexposure to administration personnel; delay in urgent evacuation of unaffected personnel.

Important example of effective administrative decisions is the management during the construction of Shelter for the destroyed Unit 4 (July – November 1986). The decision included the following: subdivision of industrial area according to the radiation situation and operation technologies (12 working zones); establishment of sanitary barriers on-site, in the 30-km zone and outside this zone; use of separate shuttle mobile means in different zones; approval of the set of temporary permissible levels adopted by the regulatory body [2,4].

Fukushima-1. Delay in urgent decisions and timely execution of works to restore electric power supply is crucial in urgent emergency management. Precautionary principle was considered for the emergency and recovery activities.

Comparison. Large uncertainties have occurred immediately after a severe accident. Important issues in early phases are risks of decision making. Range of optional decisions was very wide, from "to do any available actions up to do nothing".

— Dose monitoring

Chernobyl. Individual dose monitoring has not been carried out on April 26. Only film badges (the upper measurable level of 20 mGy) were present. Retrospective assessments of actual doses for witnesses ranged from 40-15,000 mGy. Occupational individual dose monitoring of the Chernobyl NPP personnel was satisfactorily established by 10 May. Average doses for different cohorts of EWs and ROWs are given in Table 1.

Fukushima-1. Certain difficulties of individual dose monitoring occurred in the early phase. A total of 103 people had been exposed to more than 100 mSv, primarily during March 2011. Average doses at the early phase were estimated to 21 mSv for 4,000 employees of TEPCO and contractors. Average annual dose to 25,000 EWs and ROWs was 13.4 mSv.

Comparison. Average effective doses to Chernobyl EWs and ROWs were higher approximately by a factor of 10. Individual dose distributions are demonstrated in Fig.1. One can see that the dose distributions for EWs of Fukushima were close to similar to the distribution of EWs and ROWs involved in the 30-km zone around the Chernobyl NPP.

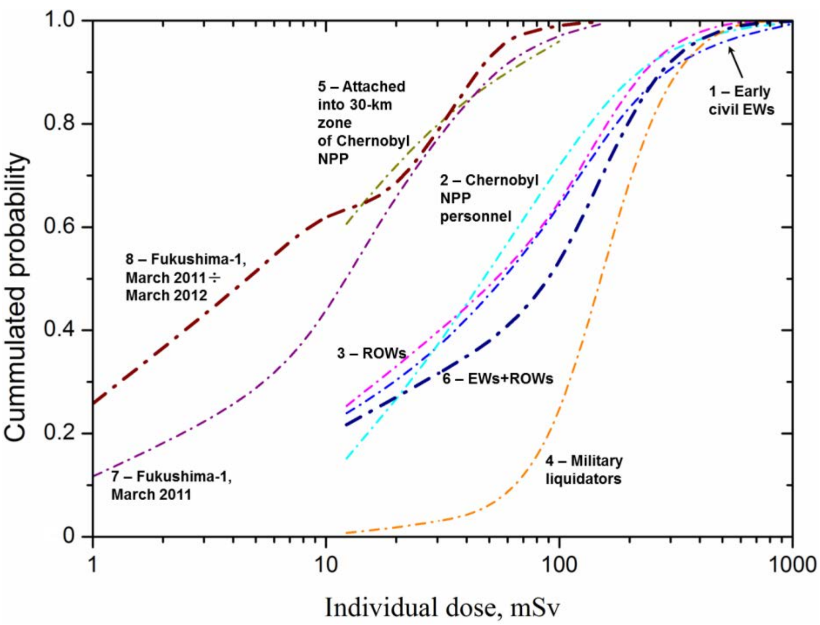

Fig.1. Comparison of the cumulative occupational doses after the accidents

CONCLUSIONS

Transition from planned exposure situation to emergency exposure situation in the case of major accidents continues to be the crucial issue of occupational radiation protection. Analyses of applied actions in Chernobyl and Fukusima-1 accidents showed two different outcomes. The first one is to achieve results through the substantial man-power and large values of individual and collective doses of EWs. The second one is to provide radiation safety to EWs, ignoring threats to the public and environment. Interaction of utilitarian and egalitarian ethics should be considered in the emergency management.

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THE INTERNAL AND EXTERNAL DOSIMETRY CHALLENGES FROM THE PAST EXPERIENCE — FUKUSHIMA DAIICHI ACCIDENT

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Abstract

Some memorable situations about radiation protection and dose evaluation concerning the Self Defense Forces, the fire-fighters, the police and TEPCO & contractor's workers are described in this paper from the practical viewpoint, based on the experience obtained in the radiation emergency medicine in early stage of the Fukushima accident.

INTRODUCTION

Radon (^{222}Rn) has been widely investigated for many years because it contributes most of the dose to the human body from exposure to natural radiation [1]. Thoron (^{220}Rn) is a radioactive isotope of radon, but due to its short half-life (55.6 s) and the lack of measurement methods as well as measuring results, it has been ignored for a long time. With the improvement of thoron measuring methods and the availability of thoron-related data, thoron exposure in some indoor environments has begun to attract attention [2–3].

Brick houses, mud houses and caves are the three typical types of rural home in China, usually characterized by uncoated surfaces from which thoron gas is easily exhaled. Thoron gas concentrations can reach quite high levels, especially in some high background regions such as Yangjiang, Guangdong Province [4] and it is appropriate that thoron exposure in rural homes should be evaluated. In indoor environments, the state of equilibrium between thoron gas and its progeny is highly variable in both space and time. Therefore, for the purposes of dose evaluation, direct measurement of thoron progeny seems to be the most reasonable approach [5].

The dose conversion factor which characterizes the dose to the respiratory tract per unit exposure to thoron progeny changes with the unattached fraction of thoron progeny and their size distribution [6]. Since the unattached fractions of ^{212}Bi and ^{212}Pb, which contribute nearly all the dose from thoron progeny, can usually be ignored in typical indoor environments, the assessment of dose from thoron inhalation can be determined from measurements of the size distribution of the attached thoron progeny and the thoron progeny concentrations.

Doses from the inhalation of thoron were assessed from thoron progeny size distribution and concentration measurements made in three typical rural indoor environments and one kind of urban indoor environment for comparison. The dose conversion factors, and annual effective doses were calculated using dosimetric methods.

METHODS AND RESULTS

— Self defence force personnel

84 personnel were engaged in discharging water operation for the cooling of the spent fuel pool (SPF) by helicopter on 17th March. UH-60JA helicopter was used for the dose measurement beforehand and CH-47JA was used to spray water. In both aircraft lead sheets were spread over

the place where the pilot and the mechanic were located in order to reduce the external exposure. To prevent the radioactive substance from flowing in, the opening under the aircraft to confirm the situation of the suspended article and ground was sealed up with a transparent, acrylic board. The crew wore the lead protective suit whose weight was approx.20 kg, protective combat suit and full-face mask. They took iodine tablets in advance to block thyroid contamination. As the air dose rate at 91m above the Unit 3 was confirmed as 87.7 mSv/h, the helicopter flew above the Unit 3 without hovering when discharging water. As a result, external exposure of all personnel was below 1mSv through four times of flights.

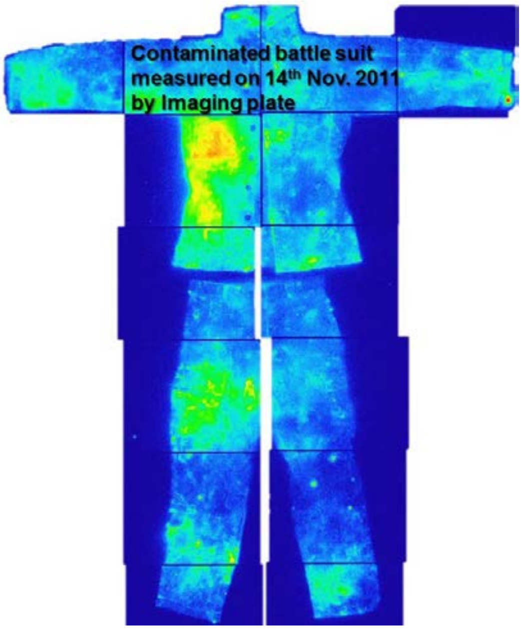

FIG.1. Contaminated battle suit worn under protective clothing

The other 84 personal mainly composed of the Central Nuclear Biological Chemical Weapon Defense Unit (CNBC) were engaged in SPF cooling operation from the groundside by using water cannon truck. At 11:01am on March 14th three vehicles were rolled in the hydrogen explosion with six CNBC personnel who had just arrived in front of the Unit 3 to achieve preliminary inspection for water discharging. They slipped out from the destroyed vehicle, and reached the OFC with difficulty. On that occasion, their surface contamination level at the distance of 10cm was 1.0 mSv/h, which was measured by Thermo RADEYE PRD-ER. Their equipment was an alarming personal dosimeter (APD), TLD personal dosimeter, full-face mask with charcoal filter, and Tyvek suit on the battle suit, which had been strongly contaminated. As the quick decontamination was indispensable, the Tyvek suit was cut by a medical scissors. During the treatment the APD sounded. As the alarm setting value was 20mSv, their external exposure was evaluated as 20mSv. The blast penetrated all of clothes and the skin of the whole body was contaminated. The decontamination ratio was at maximum 70% in spite of rapid deliberate washing with warm water and soap for 30 minutes. Figure 1 indicates the contamination distribution of the commander's battle suit, which was measured by imaging plate eight months later. Still Cs-134 and 137 could be observed and the maximum surface activity was 1800Bq/cm2. Their medical treatment and internal dose evaluation were executed in the National Institute of Radiological Sciences (NIRS) on the same day. However, in the first stage the quantification by WBC was difficult because of remaining high surface contamination and the gamma-ray pile-up as shown in Figure 2. As for the thyroid monitor, the influence of the surface contamination was a little because of its lead shield (Figure 3). The result of the dose evaluation showed that the maximum thyroid equivalent dose of them was 27.4 mSv, and the committed effective dose was 4.2 mSv by assuming type F inhalation and 5 µm AMAD. This shows that appropriate use of the charcoal filter and administration of iodine tablets in advance are extremely effective in the initial response of the nuclear accident.

— Fire-fighters

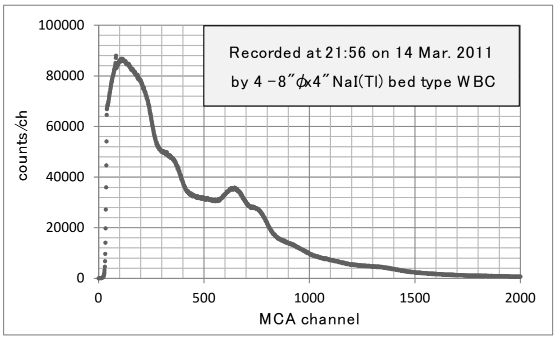

FIG.2. *WBC spectrum of a personnel involved in hydrogen explosion*

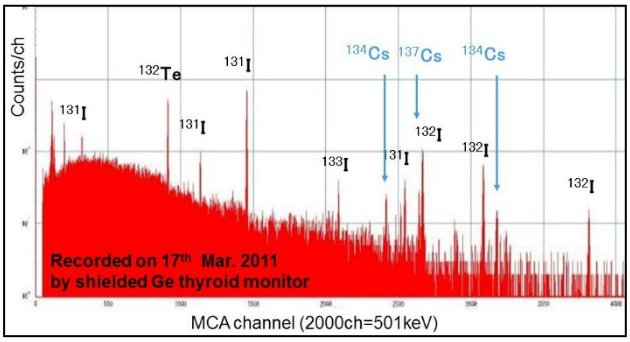

FIG.3. *Thyroid monitor spectrum of a personnel involved in hydrogen explosion*

In early phase of the accident, small number of private fire-fighters who belonged to the subsidiary of TEPCO played the most important role for reactor cooling. Among 2038 emergency workers whose surface contamination was screened in NIRS with all surface monitors which were voluntarily provided by Hitachi Aloka and Fuji Electric, some fire-fighter's contamination level was extremely high because of the skin contamination by I-131[2]. The maximum external exposure to them was 88mSv, evaluated by the same personal dosimeter as TEPCO worker. The maximum thyroid equivalent dose was estimated as 230mSv under the condition that the worker inhaled iodine for three days work uniformly and was examined eight days later.

Futaba Fire Department, the first official fire brigade which was engaged in discharging water operation for reactor cooling in very early stage, wore fire protection suit on Tyvek suit to prevent cold and contamination under insufficient support. After that, 139 fire-fighters of Tokyo Fire Department were sent on 19th March. The ambient dose rate where they worked was approx. 400 µSv/h [3]. Radionuclides detected from the surface of their personal dosimeter (Thermo) which one fire-fighter wore during this operation were indicated in Table 1. By the official report on 249 fire-fighters who were engaged in reactor cooling, the maximum external exposure was 29.8 mSv.

— Police

11 policemen were engaged in water discharging operation to SPF of Unit 3 on 17th March. The assessed doses due to internal exposure were evaluated to be less than 1 mSv. According to the record of their personal dosimeter, the maximum external exposure was 9 mSv.

TABLE.1. RADIONUCLIDES DETECTED FROM THE SURFACE OF A PERSONAL DOSIMETER ON 3RD JUNE 2011

Nuclide	Activity (Bq)	Ratio to total
Cs-134	1.93E+02	9.87%
Cs-136	1.99E-01	0.01%
Cs-137	2.61E+02	13.32%
Ag-110m	3.00E+01	1.53%
I-131	4.34E+00	0.22%
Te-129	6.39E+02	32.58%
Te-129m	8.18E+02	41.73%
La-140	9.35E-01	0.05%
Sb-125	1.34E+01	0.68%

— TEPCO and contractor's worker

Because of inundation created by the tsunami, approx. 5000 personal dosimeters were unusable. Until 1st April 2011, only 320 personal dosimeters which were gathered from buildings in Fukushima Daiichi Nuclear Power Station (FDNPS) were available. These were alarming personal dosimeters made by Panasonic using a silicon semiconductor as a photon detector, and the specifications were the same as Self-Defense Force's. The dosimeters were allocated only to the representative of same working group whose planned exposure was below 10mSv. This might cause some uncertainty in the evaluation of individual dose. In addition to the lack of personal dosimeters, access control and dose management by computer system also became impossible. So the dose records were made by handwriting, which caused confusion such as double registration, mistakes in writing and wrong personal information. When the dosimeter was left at seismic isolated building, it was also necessary to consider the dose received during the length-of-stay in the building where all workers had to eat, drink and sleep in early phase of the accident, because the maximum ambient dose rate at the emergency response center in the building was about 380μSv/h on 15th March 2011.

As all WBCs installed at FDNPS were unusable by tsunami, internal monitoring was carried out by using WBC installed at Kashiwazaki-kariwa NPS. The detector of the WBC is a large plastic scintillator, which was calibrated by Co-60. From the end of March 2011, The Japan Atomic Energy Agency (JAEA) sent mobile WBC in which Canberra FASTSCAN was installed to TEPCO Onahama coal center and started in-vivo monitoring for emergency workers. This greatly contributed to screen the worker who was internally exposed until full-fledged operation of WBC center located in J-Village.

The I-131/Cs-137 ratio in the environment was about 1.0 in the beginning of May, and 0.1 in the beginning of June. Assuming the intake of I-131 was 1% of Cs-137 and the Cs-134/Cs-137 ratio was 1.0 at the beginning of July, the contribution of I-131 to the committed effective dose was evaluated as 1.5%. Therefore, the dose of I-131 was disregarded in the measurement after July 2011.

All personal dosimeters supplied after the accident are designed for both beta and gamma measurement considering the exposure caused by Sr/Y-90.

— Thyroid monitor

The nuclides assumed as a dominating in the internal contamination were Co-60 and Mn-54 included in the corrosion product. The thyroid exposure was supposed to be evaluated by using the thyroid monitor installed at the secondary radiation emergency hospitals in case of the accident. At the Fukushima accident, with the collapse of the system on the radiation emergency medicine, only one thyroid monitor installed at the facility next to abandoned OFC was unusable because of high contamination. Then the thyroid monitoring for emergency worker was performed at NIRS and JAEA.

The HPGe spectrometer with 30 mm lead shield was used for the thyroid measurement in NIRS. The detector distance to the neck was 30 mm. However, the influence from the surface contamination or other internal activity was suppressed owing to the structure, and it was effective for the measurement at the accident. The geometric correction by subject's figure difference was not executed due to time required to grasp the shape of the thyroid by ultrasonic diagnostic equipment. For the calibration mock-iodine reference source put in the ORINS phantom was used. Through the accident a technique to use Ba-133 standard solution poured into a thyroid shape container in a neck phantom filled with water was adopted because of the changing of the activity ratio in Ba-133 and Cs-137 mixture, which were sealed in the mock-iodine. As a dose calculation programme the MONDAL that had good agreement with the IMBA under the same calculation condition was used.

It was approximately 40 days after the first day of the emergency operation when the first subject was sent to the JAEA. TEPCO and the contractor's workers were mainly examined by the JAEA. There all in-vivo measurements were performed in the shielded room with iron wall of 20mm thickness in consideration of the half- life of I-131. As for the thyroid measurement, the HPGe spectrometer, which was calibrated by the neck part of Transfer phantom of Canberra based on ANSI standard, was used. The MDA of I-131 was approximately 10Bq. The distance between the neck and the detector was 50mm. The number of subjects examined at JAEA during the period between 20th April and 5th August in 2011 totalled 560. The largest thyroid contamination by ^{131}I was 9760Bq, which was found in a male subject measured on 23rd May. His committed effective dose was calculated as 590mSv on the assumption of a single intake scenario via inhalation of elemental iodine on 12th March. The subject entered the central control room of Unit 1 and 2 even after the hydrogen explosion several times. In the control room where the employees had to stay, eat and drink, there was a high radioactivity concentration in the air to breathe. It is thought that an inadequate mask fitness of eyeglass caused the subject’s big internal exposure.

Evaluated dose is changed depending on scenario of intake. For example, when in-vivo monitoring was performed at 70 days after the first day of emergency operation and 10 kBq of ^{131}I was detected in thyroid, for single intake at the first day of the emergency operation the effective dose is calculated as 500 mSv, and for chronic intake over 20 days from the first day of the emergency operation the effective dose was calculated as 180 mSv [4].

— Whole body counter

The BOMAB phantom, based on ANSI N13.35, all WBCs, were calibrated in NIRS. The reference gel of Ba-133, Cs-137, Co-60 and K-40 were inserted in the phantoms. Using these phantoms, all WBCs, in the secondary radiation emergency hospitals and WBCs manufactured by Fuji Electric and Hitachi Aloka were also calibrated. As described above, since one or two half-life passed, it was impossible to measure the internal activity of the emergency worker in the early stage because of the high surface contamination which was mainly due to I-131 and Te-132.

CONCLUSIONS

Several of the personal dosimeters of the waterproofing type are indispensable considering worker's sweat as well as the existing flood. It should be also considered to use the commercially available dry cell, which can be supplied in any situation easily.

Administration of iodine tablet in advance and fitting of full-face mask with charcoal filter is effective in the environment where the radioiodine exists. As for the charcoal filter it is necessary to examine the filtering efficiency of radioiodine because of its high specific activity.

Data on workplace monitoring and interview to workers are important for accurate dose evaluation; especially the time and duration of intake give a decisive factor to the assessment of committed effective dose.

Further studies are still needed for the improvement of internal dose estimates especially for subjects who were suspected to have extremely high internal exposure, considering more realistic intake scenarios and the intake of other short-life radionuclides (e.g., 132I, 133I, and 132Te).

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ISOE EXPERT GROUP — OCCUPATIONAL RADIATION PROTECTION IN SEVERE ACCIDENT MANAGEMENT

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Abstract

The output was presented for the ISOE Expert Group on Occupational Radiation Exposure in Severe Accident Management (EG-SAM) which was established by the ISOE Management Board in May 2011. The objective of the EG-SAM was to contribute to occupational exposure management by providing a view on management of high radiation area worker doses. The final EG-SAM report was approved by the ISOE Management Board in November 2014. The conclusions of the final report regarding organizational and technical measures for radiation protection of the emergency workers in case of severe radiation emergency are in line with the international requirements in the forthcoming GSR Part 7.

INTRODUCTION

As Chairperson of the International System of Occupational Exposure (ISOE) Expert Group on Occupational Radiation Exposure in Severe Accident Management, I am truly honored to represent my international colleagues at this meeting of esteemed nuclear professionals.

I am here today to present to you the conclusions of our Expert Group's work on Occupational Radiation Protection in Severe Accident Management. However, first I would like to provide some introductory information about the ISOE Programme and the Expert Group on Occupational Radiation Exposure in Severe Accident Management or EG-SAM.

BACKGROUND

The Information System on Occupational Exposure (ISOE) was created in 1992 to provide a forum for radiation protection professionals from nuclear electricity utilities and national regulatory authorities worldwide to share dose reduction information, operational experience and information to improve the optimisation of radiological protection at nuclear power plants. Since 1993, the ISOE Programme is jointly sponsored by the Organisation for Economic Co-operation and Development Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA).

ISOE operates in a decentralised manner. A Management Board of representatives from all participating countries, supported by the joint NEA and IAEA Secretariat, provides overall direction. Four ISOE Technical Centres, located in Europe, North America, Asia and IAEA, manage the programme's day-to-day technical operations, serving as a contact point for the transfer of information from and to participants.

ISOE is the world's most comprehensive source of experience and information for occupational exposure management at nuclear power plants, and offers its members a variety of resources for occupational exposure management.

In April 2011, the ISOE Bureau launched an early response to the Fukushima NPP accident after communications with the Japanese participants. This response included:

- Management of high radiation area worker doses by taking into account available experiences and information from previous nuclear power plant accidents in terms of how emergency worker / responder doses were legally and practically managed, and
- Effective use of personal protective equipment (PPE) for highly contaminated areas by collecting information about the types of protective suits and other equipment (e.g. air bottles, respirators, air-hoods or suits, etc.), as well as use of high-radiation area worker dosimetry (e.g. type, quantity and placement of dosimetry) for different types of emergency and high-radiation work situations.

Detailed information was collected on dose criteria used for emergency workers /responders and its basis, dose management criteria for high dose/dose rate areas, protective equipment recommended for emergency workers / responders, recommended individual monitoring procedures, and any special requirement for assessment from the ISOE participating nuclear utilities and regulatory authorities and made available for Japanese utilities. With this positive response of the ISOE actors and interest in the situation in Fukushima, the Expert Group on Occupational Radiation Protection in Severe Accident Management (EG-SAM) was established by the ISOE Management Board in May 2011.

The objective of the EG-SAM is three-fold:

(1) Contribute to occupational exposure management by providing a view on management of high radiation area worker doses;
(2) Develop a state-of-the-art ISOE report on best radiation protection management practices for proper radiation protection job coverage during severe accident response; and
(3) Identify RP lessons learned from previous reactor accidents.

The membership of our Expert Group includes forty-five members of utility and regulators from nineteen ISOE member countries including: Armenia, Belgium, Brazil, Canada, Czech Republic, Finland, France, Germany, Japan, Republic of Korea, Romania, Russian Federation, Slovak Republic, Spain, Sweden, Switzerland, Ukraine, United Kingdom, and United States of America.

INTERIM REPORT AND INTERNATIONAL WORKSHOP

In 2013, the EG-SAM drafted an interim report comprised of six general topics contained in six chapters. These topics are as follows: (1) Radiological Protection and Organization; (2) Radiological Protection Training and Exercises related to Severe Accident Management; (3) Facility Configuration and Readiness; (4) Overall Approach for Worker Protection; (5) Monitoring and Managing the Radioactive Releases and Contamination; and (6) Key Lessons Learned from Past Accidents.

In addition, an International Workshop on Occupational Radiation Protection in Severe Accident Management – Sharing Practices and Experiences was held on 17-18 June 2014. This workshop was co-sponsored by OECD Nuclear Energy Agency and International Atomic Energy Agency and hosted by the Nuclear Energy Institute. Sixty-six persons from seventeen countries participated in this workshop, which was comprised of four plenary sessions and five break-out sessions. The workshop provided suggestions for improvement and additional points to extend the view of the interim report.

FINAL REPORT AND CONCLUSIONS

Within our report, our expert group identified two specific groups of workers: The first group comprises personnel forming the special technical, medical and health intervention teams readied in advance to deal with radiological emergency situations (e.g. firemen from public services with specific skills in radiological interventions, workers from the plant, etc.). This group should be involved in intervention on the damaged site (to secure the situation, to give first aid to victims, etc.). They should be more dedicated to intervention in the vicinity of the damaged site (environmental measurements, facilitation of the evacuation of people, etc.). This group should have appropriate equipment, including personal passive and operational dosimeters with regard to the particular nature of the radiological risk when they participate in an intervention. They should also receive special and relevant training and information on the risks at the beginning of the emergency situation.

The second group comprises persons not belonging to special teams, but intervening as part of the tasks within the scope of their competence (e.g. firemen from public services, experts in the field of measurements, medical assistance, etc.). They should be given appropriate information on the risk associated with exposure to ionizing radiation, possess adequate individual protection equipment and dosimetry and receive special and relevant information on the risks at the beginning of the emergency situation or upon their arrival near the affected site.

The final report was approved by the ISOE Management Board in November 2014 with the final conclusions:

Extensive Emergency Response Plans should be developed for protecting emergency workers/responders and the public. These plans should thoroughly address emergency worker/responder staffing, command and control, emergency facility design, emergency response procedures, enhanced radiological controls including dose reference levels and instrumentation, on-site decision making, emergency worker/responder training and communications.

The development of anticipatory training related to severe accident management is imperative for all emergency workers/responders. This includes development of a SAM training and qualification program that addresses emergency worker/responder actions within elevated radiation fields and response during stressful situations. Emergency drills and exercises should be routinely conducted to evaluate emergency worker/responder performance. These activities should be critiqued, and if applicable, lessons learned incorporated into training programmes, procedures and guidelines, as well as organizational aspects of accident management.

Effective implementation of a RP programme during a severe accident may be significantly impacted by the plant's facility configuration and access controls. Properly designed and operated habitability controls such as facility shielding and filtered ventilation systems, effective communications systems, installed radiation monitoring instrumentation, portable radiation detection equipment, radiochemical analytical laboratory capability for high activity samples, and a variety of worker PPE are essential for response to a severe accident.

Radiological Protection of the emergency worker/responder, including the establishment of individual exposure reference levels, extensive work controls, and thorough radiological exposure controls are necessary to maintain emergency worker/responder radiation exposures ALARA. State-of-the-art radiation detection equipment must be properly used to effectively detect external and internal exposure to emergency workers/responders. During our analysis of international dose reference levels, we identified a range of values from 50 mSv to 500 mSv for equipment-saving actions and a range of 200 mSv to greater than 500 mSv for life saving actions.

During the emergency and post-accident mitigation phases, radioactive and contaminated materials released internally and externally from the affected facility require extensive radiological controls to avoid or minimize radiation exposures to emergency workers/responders and the public. Radioactive releases must be monitored and controlled within the plant and offsite using robust monitoring equipment and engineering controls as necessary.

The lessons learned from past accidents such as Three Mile Island, Chernobyl and Fukushima Daiichi teach us that comprehensive emergency plan development, routine training and exercising (including stressful, time-limited activities) of emergency all workers/responders, remote radiological monitoring, high dose detection equipment and robotic equipment are imperative when responding to a severe accident at a nuclear power plant. Continuing the collection and analysis of feedback experience from the past accidents is an essential source of improvement of the preparedness of severe accident management.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 6

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INTRODUCTION

Topical Session 6 dealt with occupational radiation protection issues and challenges in nuclear or radiological emergencies and in existing (post-accident) exposure situations. Five contributed papers [1-5] have been submitted to this Session. These papers address three different areas: personal protective equipment [1-2], retrospective dose reconstruction for estimating doses in cases of localized radiation injuries [3], and assessment of potential and actual working conditions with the aim to ensure radiation protection and safety of workers including emergency workers [4-5]. These papers are summarized below.

SUMMARY

Orion et al. (Israel) [1] presented a novel device which can be used by workers, including emergency workers, as personal protective equipment to shield the pelvic bone marrow from acute exposure and from cumulative exposure to gamma radiation. The aim of this device is to protect a volume of the bone marrow which is sufficient for hematopoietic reconstitution and thus can prevent lethal acute radiation syndrome at an exposed individual even at very high radiation doses (greater than 9 Gy). The paper presented this device to be belt-like personal protective device for the pelvic bone marrow that contains radiation-attenuating component of numerous layers of uniquely cut lead sheet layers. These layers create a topography that reflects the unique anatomy of the pelvic marrow. The paper presented how the device has been tested (using a life size phantom model of a human body being exposed to Cs-137 in a configuration presented as a fallout, ensuring isotropic exposure and using thermoluminescent dosimeters) and how the volume of live bone marrow remaining following 9 Gy whole body exposure has been determined (by determining the dose-to-volume histograms and considering the human bone marrow radiosensitivity). Results of these tests showed that the quantity of the remaining live bone marrow is significant (about 127 grams) and it exceeds the minimum quantity of live bone marrow necessary for reconstitution of a lethally irradiated average sized adult (about 50 grams).

Ozil et al. (France) [2] considered ventilated pressurized personal protective equipment and non-ventilated personal protective equipment against the requirements set forth in the European Directives (EC89/686 and EC89/656) on personal protective equipment. The requirements set forth in the European Directive EC89/686 regarding the performance of the personal protective equipment relate to: ensuring highest level of protection against irradiation and contamination; minimization, to the extent possible, of the risks associated with the personal protective equipment itself; and its comfort and efficiency. The paper concluded an improved performance of ventilated pressurized personal protective equipment in comparison to non-ventilated personal protective equipment in relation to: full body protection against skin contamination; protection against inhalation; and heat stress removal.

Lima et al. (Brazil) [3] presented a state of the art reconstructive dosimetry used to estimate radiation doses incurred by an operator involved in a radiological accident and a comparison among the results of dose calculations using different dosimetry methods and the clinical observation based on the localized radiation injuries. The radiological accident under consideration happened in May 2000 in Brazil and involved a dangerous source, i.e. Co-60 with activity of 2.11 TBq, used for industrial radiography in which the operator kept his left hand very close to the radioactive source for approximately 30 seconds during routine exposures. The clinical observations of the localized radiation injuries following the accidental exposure led to assessment of absorbed dose between 10 and 20 Gy to the most affected fingers of the operator. The work done to retrospectively reconstruct doses received by the operator in his left hand involved physical, biological and computational dosimetry methods. The computational dosimetry method used involves the Brazilian Visual Monte Carlo computation program along with human body voxel simulator to calculate the relevant doses and to simulate the accident. The results presented show that the distribution of absorbed doses on the operator’s left hand as estimated using the physical method and the Visual Monte Carlo calculation program are in accordance with the doses based on the clinical observations. The paper also compared the results obtained through a physical method with those obtained through the Visual Monte Carlo calculation program. On the basis of the comparison among the results obtained by the two methods, the paper concluded the suitability of Brazilian Visual Monte Carlo calculation program for estimation of distribution of doses to the hands with possibility for its use to promptly estimate radiation dose at localized radiation injury.

Lin et al. (China) [4] assessed the working environment under accident conditions in the safety building and the main control room of a nuclear power plant with regard to airborne activities and doses to be incurred by emergency workers. The purpose was identification of safety measures to be implemented in the design of the nuclear power plant so that habitability of the safety building and the main control room is ensured under accident conditions in compliance with the respective Chinese regulations. The paper analysed the source of activity concentrations in the safety building and the main control room taking into account the behaviour of the emergency habitability system and the inner close loop ventilation system. The doses assessed showed that the main contribution to doses of workers in the main control room were due to the airborne activity, although at levels that comply with Chinese regulations. On the basis of the analysis, the authors proposed two design measures (double air intakes for the emergency habitability system and inner close loop ventilation system) to be considered with the aim to reducing the airborne activity in the main control room and therefore, to ensure its habitability.

Kalashnikova (Ukraine) [5] elaborated the strategy of the Kiev State Interregional Specialized Enterprise for ensuring a radiation protection and safety of workers undertaking recovery work in near-surface storages of radioactive waste (in total, three storages commissioned in 1962 in Ukraine) which had suffered a degradation of the integrity of protective barriers and subsequently resulted in a release of radioactive material in the air and ground water. These degrading conditions were determined in the 90’s while the overall recovery work was planned in 2011. The paper presented three planned stages of the recovery work: the first included detailed survey of the radiological conditions at the site and pumping the contaminated water from two storages; the second included removal of the radioactive waste from the storages, placing it in adequate containers and building of a new storage for these containers; and the final stage included moving of these containers to an existing repository in the Chernobyl exclusion zone. The first stage recovery work was completed in the period 2011-2013 after careful planning to address the hazardous conditions present at the site which resulted in total effective doses among engaged workers of below 1 mSv during this period (from both internal and external exposure). The recovery work of the second stage is under preparation for one of the three storages that are considered to be the safest in terms of on-site hazardous conditions and the inventory of radioactive waste present. The recovery work at this storage is envisaged to provide insights into necessary improvements of radiation protection and safety measures planned for the recovery work at the remaining two storages. The preparations take into account gaps identified in the existing legal framework of Ukraine regarding management of historical radioactive waste, the limited past experience, available technological solutions and necessary measures to be applied for protection of workers. In conclusion of this paper, effective doses of workers who were engaged in the second stage of the recovery work were projected to be below 12 mSv per year. This value is consistent with the occupational dose limit for any normal practice involving ionizing radiation sources in Ukraine.

CONCLUSIONS

As such, the contributed papers are not exclusively associated to occupational radiation protection of emergency workers but they have their relevance to other exposure situations or to other individuals that may be affected by an emergency too. The above summarized papers clearly indicate that proper consideration of the anticipated hazardous conditions in which emergency work or recovery work may need to be undertaken, can provide useful insights into measures that need to be implemented for protecting emergency workers and recovery workers. In addition, the papers demonstrated that in situations that do not require urgent decision-making, detailed planning of the recovery work is essential and more stringent requirements for occupational radiation protection as for a planned exposure situation can be required. Furthermore, proper personal protective equipment should be available and can be selected to meet the expected conditions in which emergency work or recovery work is to be undertaken. This equipment needs to provide for protection against both radiological and non-radiological hazards present in the working environment as well as in relation to its use. Finally, prompt estimation of doses incurred in an emergency is essential in terms of identifying the need for the necessary medical attention. Without any intention to underestimate other methods available, the presented computational code – the Visual Monte Carlo – has been demonstrated as useful in prompt estimation of doses in a radiation emergency.

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[5] Z. KALASHNIKOVA, The Strategy Ensuring Radiation Safety of the Liquidators in a Radiation Accident.

CHAIRS' SUMMARY OF TOPICAL SESSION 6

Topical Session 6 included a keynote address by Mr. S. Yasui, Ministry of Health, Labour and Welfare (MHLW) of Japan and three topical presentations delivered by Mr. M. Savkin, Nuclear Safety Institute of Russian Academy of Sciences, Russian Federation, Mr. T Suzuki, Chiyoda Technology Co., Japan, and Ms. E. Anderson, Nuclear Energy Institute, USA. Summary of contributed papers was presented by Ms. S. Nestoroska Madjunarova from IAEA.

The lecture of S. Yasui was entitled "Lessons Learned: Radiation Protection for Emergency response and Remediation / Decontamination Work Involved in TEPCO Fukushima Daiichi NPP Accident". The keynote address focuses on problems that occurred during emergency work at TEPCO Fukushima Daiichi NPP in 2011 and extracted lessons learned from the experiences for radiation protection and provided guidance regarding preparedness for a similar accident in the future. The MHLW faced difficulties in determining how radiation protection systems, intended for planned exposure situations, should be applied to the existing exposure situation. In this situation, the MHLW had no option, but to consider the existing radiation protection systems and make every effort to adapt them to the current situation. The problems that had been faced to and lessons learned were aggregated into two groups, which were related to radiation protection and medical care of emergency workers.

The following gaps in radiation protection of emergency workers have been underlined by the MHLW during early phase of response to Fukushima accident:

- Inappropriate monitoring of external exposure;
- Inappropriate monitoring of internal exposure;
- Inappropriate dosimeter circulation management and exposure control;
- Inappropriate registration of the emergency workers; and
- Inappropriate training of some groups of emergency workers.

Problems in the medical management of emergency workers were also underlined and linked with the loss of the designated hospitals (which were located at the affected territory in vicinity of the Fukushima Daiichi) due to the natural catastrophe produced by the combination of the earthquake and the tsunami.

Lessons learned by the MHLW from initial phase of response to the Fukushima accident were promptly implemented in national regulation on radiation protection of emergency and recovery workers. It was emphasized that the international guidance documents on emergency preparedness and response issued by the IAEA were an important support to the government and NPP operators for performing necessary measures for radiation protection of emergency workers, particularly taking into account the lack of national regulations for emergency response.

The presentation of Mr. M. Savkin was entitled "Comparison of occupational radiation protection following the Chernobyl and Fukushima accidents". The major goal of the presentation was to compare framework and results of radiation protection of emergency workers during Chernobyl accident (USSR, 1986) and Fukushima accident (Japan, 2011). The following areas were used for comparison:

- Nation requirement on limitation of exposure of emergency workers;
- Management of exposure of emergency workers in severe accident conditions; and

- Monitoring of individual exposure of emergency workers in severe accident conditions. The major conclusion of the performed analysis was that transition from planned exposure situation to emergency exposure situation in a case of severe NPP accident is the key problem of radiation protection of emergency workers. The problem rose up during the Chernobyl accident in 1986 and appeared again in 2011 during the Fukushima accident.

An important issue highlighted by Mr Savkin was the ethical dilemma during an emergency for handling the restrictions of exposure of rescuers. Should teleological, consequential, ethical principles be used (namely, 'mind the ends, which justify the means')? or, should deontological ethical principles be used (namely, 'not do unto others what they should not do unto you').

The presentation of Mr. T. Suzuki was entitled "The internal and external dosimetry challenges from past experience: Fukushima Daiichi accident". The major goal of the presentation was to describe some memorable situations about radiation protection and dose evaluation concerning the Self Defence Forces, the fire-fighters, the police and TEPCO and contractor's workers from the practical viewpoint of qualified experts involved in radiation monitoring of emergency workers. Several important operational lessons were learned from the personal experience. The major ones are related to the control of internal exposure. It was recognized that the thyroid monitor was not set up in Fukushima Daiichi NPP at all. WBC was calibrated only for monitoring Co-60 and Mn-54 and could not have been directly used for monitoring of I-131, Cs-134 and Cs-137 in the event of nuclear emergency. Unfortunately, as concluded in presentation, that situation is common for any electric power company. Alternative WBC in NIRS was too sensitive that is was not possible to use it in monitoring of highly internally contaminated emergency workers.

The presentation of Ms. E. Anderson was entitled "ISOE Expert Group: Occupational Radiation Protection in Severe Accident Management". The major goal of the presentation is to present to the conference the conclusions of ISOE Expert Group on Occupational Radiation Exposure in Severe Accident Management (EG-SAM) which was established by the ISOE Management Board in May 2011 with three-fold objective:

- Contribute to occupational exposure management by providing a view on management of high radiation area worker doses;
- Develop a state-of-the-art ISOE report on best radiation protection management practices for proper radiation protection job coverage during severe accident response; and
- Identify RP lessons learned from previous reactor accidents. In 2013, the EG-SAM drafted an interim report comprised of six general topics:
    - Radiological Protection and Organization;
    - Radiological Protection Training and Exercises related to Severe Accident Management;
    - Facility Configuration and Readiness;
    - Overall Approach for Worker Protection; and
    - Monitoring and Managing the Radioactive Releases and Contamination.

Key Lessons Learned from Past Accidents. In addition, an International Workshop on Occupational Radiation Protection in Severe Accident Management – Sharing Practices and Experiences was held on 17-18 June 2014. This workshop was co-sponsored by OECD/NEA and IAEA and hosted by the Nuclear Energy Institute, USA. Sixty-six persons from seventeen countries participated in this workshop. The final EG-SAM report was approved by the ISOE Management Board in November, 2014. The conclusions of the final report regarding organizational and technical measures for radiation protection of the emergency workers in case of severe radiation emergency are in line with the international requirements in the forthcoming GSR Part 7.

Ms. S. Nestoroska Madjunarova from IAEA presented a summary of 5 contributed papers from Brazil, China, France, Israel and Ukraine. They were focused on the following issues:

- Personal protective equipment;
- Retrospective dose reconstruction in case of a localized radiation injury; and
- Assessment of potential and actual working conditions as a basis for planning and implementing measures to protect emergency workers in emergency exposure situation and recovery workers in existing exposure situation.

The Session 6 was complemented with a 20-minute discussion about the key points of occupation radiation protection of emergency workers.

Mr. Peterson, NRC, USA, questioned about the capabilities for monitoring of internal contamination and external exposure of emergency workers, which had TEPCO before the accident and how they were used during the response.

Mr. Pappinisseri-Puthanveedu, IAEA, questioned about the party which had the primary responsibility for monitoring and reconstruction of individual doses of emergency workers during the Fukushima accident.

Mr. Weiss, Germany, raised attention to the ISOE EG-SAM on the necessity to elaborate a curriculum for training of emergency workers on occupation radiation protection.

Mr. Weiss, Ms. Kesminiene, IARC, France, and Mr. Rannou, IRSN, France drawn attention to the secretariat on the problem of development of recommendations on medical follow-up of workers received high doses.

Mr. Cool, NRC, USA, emphasized the importance of transition from normal to emergency operations for occupational radiation protection of emergency workers.

Some general conclusions follow:

- The time allocated to this complicated subject did not permit a full discussion of the many issues. It was recommended that the IAEA and ILO should consider calling for a meeting (e.g., a symposia) fully dedicated to the protection of emergency workers, taking into account future planned activities in this area.
- While a long tradition of occupational health and safety policies exist under the framework of ILO, which also covers the current international occupational radiation protection policy, it is not clear how these policies cover emergency workers. This issue requires a priority attention and it should include ethical considerations that sometime could be competing.
- While the international standards on emergency preparedness and response (existing as well as forthcoming) provide a comprehensive requirements and guidance for

protection of emergency workers, further work is necessary in this difficult area to support their practical implementation.

- Notwithstanding, the key urgent issue remains the implementation of the international requirements and guidance on protection of emergency workers in the national framework for occupational radiation protection.
- The issue of unclear and competing responsibilities for occupational radiation protection is particularly crucial during emergencies because, as the Fukushima accident demonstrated once again, most of the workers involved were not the traditional 'nuclear' workers under the responsibility of the licensee. International undertakings are not fully clear on the responsibilities of governments and regulatory bodies on one side, licensees, undertakers and registrants on the other side, and the ultimate main responsible, the employer, on the other side.

The quantification of radiation exposure during an accident continues to be an issue that requires further attention considering that the radiation protection quantities in normal operations have been defined for low doses.

TOPICAL SESSION 7:

OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO NATURALLY OCCURRING RADIOACTIVE MATERIALS AND COSMIC RAYS

Chairpersons: P. P. Haridasan, IAEA and P. V. Shaw, United Kingdom

CHALLENGES IN IMPLEMENTING THE CHANGE IN REGULATIONS IN THE NORM INDUSTRY

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Abstract

It seems evident that the revised BSS would provide greater clarity on the control of exposure to natural sources although this task will be far from trivial, still retaining some complexities. The description and evaluation of the most important challenges, in relation with the implementation of the new BSS in the NORM industries will be to form the core of this lecture.

CHALLENGES AND CURRENT STATUS

It was about twenty years ago when some countries, mostly European, started to introduce measures to regulate exposures arising from a variety of natural sources, in particular from minerals other than those associated with the extraction of uranium. Two important milestones in this regard were the establishment of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (IAEA, 1996) and the European Council Directive 96/29 of Euratom published the 13 of May 1996, both containing provisions for protective measures against significantly increased exposures of workers and members of the public to natural sources.

Only one year after the publication of the mentioned European Directive, the first specific International NORM Conference was held in Amsterdam in response to the concern generated in the European chemical industry about the implications of its implementation. The novelty of these regulations, the lack of experience of all the actors involved (regulators, industries, radioprotection specialists...), and also the confusing treatment of some key points of the international standards, were the cause of a certain chaos during the first few years. From 1996 until now, the advances in radiation protection in the NORM area have been evident, acquiring the issue a worldwide dimension not existing twenty years ago. New regulations for the control of exposures from NORM were established and the knowledge about levels of exposure has clearly improved, diminishing the controversial aspects associated to this field in NORM industries. Nevertheless, all the controversial aspects have not disappeared, as it was reflected in 2007 during the NORM V conference, where a key question was whether there was a chaos or consensus in relation to managing NORM. The answer was that there was still a little of both. Although in a lesser extent along the time, a perception in the community involved in the

NORM issue is that the treatment of exposure to natural sources in international standards has been unnecessarily complicated and confusing, inducing misunderstandings and differences in their interpretation, mainly in the basic and essential concepts.

Only a few months ago there were published the new version of the International Basic Safety Standards (BSS), which replaced the published ones in 1996. The requirement in the new BSS is in line with the 2007 Recommendations of the ICRP, involving in fact three types of exposure situations (planned exposure situations, existing exposure situations and emergency exposure situations). Exposure to natural sources continues to be the subject of the requirements for existing exposure situations, but exposure control, is based on the use of the so-called reference levels, which are defined as levels of dose or risk above which these are judged to be inappropriate and below which optimization of protection should be implemented. Reference levels replace the concept of "action levels" included in the old BSS and defined as the levels of dose rate or activity concentration at or below which remedial actions were not necessary.

Only a few exposures to natural sources, are subject to the requirements for planned exposure situations. These are exposures to material with a concentration exceeding 1 Bq/g for the U and Th decay series, or 10 Bq/g in the case of 40K. In addition, numerical criteria for exemption and clearance of NORM have been included for the first time; the exemption was determined on the basis of dose commensurate with the natural background (about 1 mSv /year) and the clearance criteria for NORM 1Bq/g for U and Th series radionuclides and 10 Bq/g for 40K.

It seems evident that the revised BSS would provide greater clarity on the control of exposure to natural sources although its application will be far to be trivial. The new BSS has simplified its structure and, in its revision, has covered one of the main objectives: to improve the treatment of exposure to natural sources in international standards. This coverage has been mainly performed through the greater use of quantitative criteria rather than qualitative criteria.

During the last years it became clear that a considerable progress was achieved worldwide towards harmonization of standards and regulatory approaches for the control of exposures to NORM. The tendency observed in the first months of implementation of the new BSS to simply interexchange the concepts of action levels and reference levels should be corrected. The "reference levels" have sometimes been used as limits defeating the purpose of optimization.

The change from "action levels" to "reference levels" is far from being anecdotic. In addition to an evident change in the philosophy of regulation, the selection of numerical values for the "reference values", quite identical to the previously established in the old BSS for the "action levels", resulted in an increase in the stringency of protection measures in existing exposures situations, principally through the removal of what was effectively a lower bound on the application of the optimization process. This increase in the stringency, in the case of radon is based on the fact that the ICRP now considers the dose per unit activity concentration of inhaled radon to be significantly higher than previously assumed. However, the practical coincidence in numerical values between the reference levels indicated in the new BSS and the action levels associated to the old BSS, has provoked the commented tendency to dismiss simply the change of action levels to reference levels as a change in terminology that needs to be avoided.

In some cases, also the concepts of planned and existing exposure situations are not fully understood in terms of practical information. In other words, there are situations where some doubts can appear about which type of requirements (for planned or existing exposure situations) should be implemented. By default, these cases should be treated as existing exposure situations and only in exceptional cases as planned exposure situations. This follows from the philosophy of the BSS that treats the great majority of exposures to natural sources as an existing exposure situation. The selection performed in these unclear cases is only based on taking practicability, because the exposure should be controlled regardless of the type of situation.

Obviously, although standards have been developed for the NORM industry in general without exceptions, it is clear that individual NORM industries are very different as are the practical radiation protection challenges, they face. No single approach is appropriate for all industrial processes (NORM industries), because the nature and level of the radiological risk varies considerably from one industrial process to another. In NORM industries, most of the actions taken to comply with regulation are specific situations that are very difficult to generalise. The idea of a common protocol to control the exposures in all the NORM industries should be forgotten, being substituted by an industry-specific approach. The importance of this point is reflected in the publication of the “positive list” of industries proposed for Europe and in the IAEA industry specific safety reports. Through the individual studies performed in NORM industries, it is also clear that in the majority of the NORM industries the worker’s doses are lower than 1 mSv/year. There are only a few exceptions related to U/Th mining and processing, rare earths extraction etc., where there is a potential for higher exposures if an adequate control is not implemented. Additional studies in NORM workplaces where dose optimization is needed should be performed, with special emphasis in the evaluation of alternative approaches to decrease occupational doses. On the other hand, it is interesting to note that the methodologies for realistic assessment of worker doses suffer from non-standardised approaches. The emphasis should be put on the actual monitoring data (individual and workplace) to ensure that the dose estimates are realistic. In particular, it is important to emphasize that the standardisation in assessing occupational inhalation doses suffers from a tendency to use simplified non-validated approaches.

The lack of proper development of standardisation is even found in the NORM industries employing analyses determine radionuclide concentrations in the raw materials, products and residues. There is a clear industrial lack of sufficient infrastructure to analyse and interpret radionuclide concentrations and there is an associated lack of qualified experts in radiation protection in the NORM industries, and there is a lack in the development and standardization of field methods for activity analysis in industrial samples. These lacks are partially covered by some radiation protection service companies, but hardly in the way of proper understanding and interpretation of the results.

A particular case that needs special attention refers to some service companies specialized in maintenance and cleaning activities for some NORM industries. The workers of these companies do not have a defined workplace (it changes along the time) and they can be subject to no trivial doses. A strict dosimetric control of these workers should be performed, taking into consideration that the changes in the workplaces can involve overpassing of national borders.

A key issue associated with the application of the new regulations in NORM activities is the legacy issue. Many NORM related industrial sites were abandoned in the past with little or no remediation and inefficient residue management. Such sites may include tailing facilities, fertiliser plants, thorium mantle factories, metal refineries, old oil production fields, etc. Many of these legacy sites now need remediation, because they can be in the vicinity of urban centres. Requirements for existing exposure scenarios should be applied and coordinated on international scale. In addition, the design and application of the remedial actions in order to satisfy the regulatory requirements, should be complemented with the detailed exposure monitoring of workers. A strict assessment of the different routes of occupational exposure should be performed in each individual case, and if needed, radiological monitoring should be adopted.

Finally, another important issue in NORM industries is the management of NORM residues/wastes. For some NORM industries, especially those producing low or medium volume residues with higher activity concentrations, a suitable disposal repository is the only solution. It has been accepted that these NORM residues may be disposed in a manner similar to that for other hazardous wastes. For residues with a moderate content of radionuclides there is an increasing acceptance to rather recycle than dispose. In case of waste disposal, exposure control of the workers involved in its management and maintenance should be assured.

PRACTICAL EXPERIENCE IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION AND TRAINING IN THE OIL AND GAS INDUSTRY

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Abstract

Natural radiation consists of cosmic radiation and the radiation arising from the decay of naturally occurring radionuclides. Naturally Occurring Radioactive Material (NORM) may accumulate in many localities along the oil and gas production process. Radionuclides identified in oil and gas streams belong to the decay chains of the naturally occurring radionuclides 238U and 232Th. Uncontrolled activities associated with enhanced levels of Naturally Occurring Radioactive Material (NORM) can contaminate the environment and pose a risk to human health. This paper aims to share the experience achieved by the oil and gas industry in Brazil, implementing occupational radiation protection to mitigate occupational and environmental risks. By the adoption of methods to identify where NORM is present and by the control of NORM-contaminated equipment and waste it was possible to establish measures to protect workers and the environment to meet the recommendations of the International Atomic Energy Agency, expressed in its publication Safety Series 115 (IAEA, 1996).

INTRODUCTION

The risk due to the exposure to natural radiation can be mitigated by the adoption of measures aimed at identification of NORM presence and by the monitoring of NORM-contaminated equipment and waste [3].

The objective of this paper is to share the experience achieved by the oil and gas industry in Brazil in implementing occupational radiation protection to meet the recommendations of the International Atomic Energy Agency, expressed in its publication Safety Series 115 (IAEA, 1996). Challenges and opportunities yet to overcome by the sector due to NORM presence in its operational activities were also presented.

NORM FORMATION IN THE OIL AND GAS INDUSTRY

Radioactive materials such as uranium and thorium that were incorporated during the Earth’s crust formation normally exist at very low concentrations in rock reservoirs. The decaying process of these unstable radioactive elements produces progeny radionuclides that can be transported from the reservoir to the surface while oil & gas products are being mined [3].

Changes in temperature, pressure, geochemical conditions and flow regime, suffered by such fluids during the production process might lead to the deposition of such precipitates within the production rigs and process plant, resulting in significant loss of production and rising the levels of ionizing radiation above background.

Radionuclides mobilized and usually appearing on sludge, sediment and scale are ^{226}Ra, ^{228}Ra and ^{210}Pb, all from the series of ^{238}U and ^{232}Th. The composition and the specific activity of radionuclides in sludge, sediment and scale, encountered in oil production vary widely and depend on many operational factors.

The existing data from the literature indicates that NORM wastes contain activity concentrations of ^{226}Ra ranging from undetectable levels to more than 1000 kBq/kg. The activity concentrations of ^{226}Ra in NORM can be much higher than the recommended values established. The production of large amounts of NORM and the associated radiological hazards has been extensively described [4].

NORM IN THE OIL AND GAS INDUSTRY IN BRAZIL

The offshore exploration in Brazil initiated in the early 70s in Campos Basin and the first oil production initiated in 1977. The first NORM scale occurrence was noticed in 1988, and since then a strong protection partnership was established with the Institute of Radiation Protection and Dosimetry (IRD), with the objective to conduct survey, sampling and analysis programme and to determine the extension of NORM generation. Application of the best practices and knowledge concerning radiation protection in the oil and gas industry was another objective of this partnership.

The IRD institute is one of Brazil´s most important centres of expertise in radiation protection, dosimetry and metrology of ionizing radiation, and its activities cover all areas in which man and environment can be exposed to radiation, i.e. power generation, medicine, industry and research. The areas of specialization include human and environmental radiation protection and nuclear and radiological emergency response. Radionuclides such as ^{226}Ra, ^{228}Ra and ^{228}Th were found in scale samples from Brazilian oilfields and their concentration ranged from 16.2 to 93.2 $kBq.kg^{-1}$ for 226Ra, from 4.0 to 36.9 $kBq.kg^{-1}$ for ^{228}Ra and from 4.5 to 18.5 $kBq.kg^{-1}$ for ^{228}Th. Measured values for sludge samples ranged from 0.13 to 331 kBq.kg-1 for 226Ra, from 0.10 to 245 kBq.kg-1 for ^{228}Ra and 0.10 to 272 $kBq.kg^{-1}$ for 228Th. However, the ^{226}Ra/ ^{228}Ra activity ratio was similar for both, and the mean values were (1.9-1.2) and (2.0-1.4) for scale and sludge, respectively [5].

— Occupational exposure

Taking into account the current working time per employee of about 2000 hours in a year in field activities, no significant radiological impact on workers was expected from NORM in oil and gas plants. However, as the potential additional annual dose for individuals due to external exposure can be higher than 1.0 mSv, some restrictions from the occupational point of view should be applied. Moreover, in view of the observed mean values of ^{226}Ra, ^{228}Ra and ^{228}Th, the concentrations of 37, 23 and 10.5 $kBq.kg^{-1}$ in scale and 107, 77 and 77 $kBq.kg^{-1}$ in sludge cannot be regarded as exempted, therefore creating an urgent need for the establishment of suitable technical guidelines for this sector. [6].

Measured gamma dose rates inside onshore sludge deposits ranged from 0.2 to 2.0 $\mu Sv.h^{-1}$ and they increased up to 0.3 $mSv.h^{-1}$ when taken sludge barrels on surface. Since these deposits are well ventilated, radon levels inside were expected to be low and the mean value of 6 $Bq.m^{-3}$ was measured during several working days period. Due to the maintenance requirements and operational dynamics of constant removal and cleaning of scale deposits, thermoluminescent dosimeters were also installed close to the equipment and corridors.

The average activity concentration per mass unity of sludge collected from offshore equipment was 184 Bq/g and the observed maximum value was 578 Bq/g. A permanent ^{226}Ra activity concentration was found higher than that of ^{228}Ra, which is probably due to geological formation. The dose rate measured in an offshore installation indicate, in most places, values above the background level from 0.2 µSv/h to 1.0 µSv/h [7].

— Occupational radiation protection measures after assessment

The NORM assessment established by the Institute of Radiation Protection and Dosimetry brought an understanding of the mechanism and behaviour of radioactive materials in the exploration and production of oil and gas, making it possible to expand the assurance of protective measures and control. The general principles of radiation protection were primarily implemented by means of good protective measures at the workplaces. Hence, exposure control and adequate dosimetry were the most critical components of a health and safety programme. The need to evaluate exploration and production oilfields, both onshore and offshore areas, has led to research and adaptation of technological innovations that could facilitate and expedite the survey. Individual backpack and car mounted with detection equipment were used to provide both determination of source term and global positioning systems (GPS) in oilfield areas. As a result, great improvement was achieved in the sector, both in terms of time saving compared to the initial radiometric surveys and increase in the size of the area covered by the research. Initial investigation constituted the first step for implementing a sound program of radiation protection measures.

— Training and skills of workers

Developing a skilled workforce appeared to be vital for acquiring the necessary protection measures for the future and ensuring benefits of occupational safety. Corporations which offered training of their staff can benefit from increased productivity, improved morale, higher employee retention and an enhanced business performance. Investing in employees enabled them to feel more valued, thereby increasing motivation, which can have tangible effects on occupational protection. A team of Radiation Officers was established and certified since 2006, thus serving as the front line in addressing the NORM issues, monitoring and implementation of protection measures for workers and environment in exploration and production operational units.

CHALLENGES AND OPPORTUNITIES

— Legal aspects and framework

One of the most critical aspects of NORM in the oil and gas industry is the lack of a regulatory framework. A critical review of Brazilian Standards concerning nuclear and radioactive industries is being done. ,A concern expressed during the past international events promoted by the IAEA Fifth international symposium on Naturally Occurring Radioactive Material (NORM V) reflected the urgency on the need for moving towards a harmonized approach to the management of exposure to NORM, especially in the oil and gas sector, taking into account that raw products and marketing are traded internationally on a very large scale.[8].

While there had been some progress towards harmonization at the international level, the question remained as to whether consensus on this matter was really being achieved. Of a particular concern were the numerous and significant inconsistencies between countries in the application of regulatory control measures. Instances were mentioned of countries extending the scope of regulation down to values of activity concentration that were five or ten times lower than those agreed upon in international forums.[9].

— Disposal options

In Brazil, little regulations have been specifically addressed to handling and disposal of NORM waste from the oil and gas industry, although many technological options for final disposal of wastes containing NORM are well known and commercially available through the world.

Almost all methods of final disposal of NORM from oil and gas industry used worldwide can be applied to Brazil, except for the offshore discharge, near-shore discharge and landfill. Other methods as onshore landfill, sewer discharges, smelting and incineration, despite not having legal restrictions, may release contaminants to the environment. The most appropriate methods, complying with the Brazilian legislation, are the re-injection, in situ, downhole abandonment, encapsulation and downhole disposal, onshore built disposal facility, disused mine works and disposal in salt caverns [10].

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REGULATORY STATUS AND CHALLENGES IN NORM INDUSTRIES IN CHINA — COAL AND RARE EARTH MINING

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Abstract

The background information and basic status related to industries processing NORM, are introduced along with the natural radiation level in China. Radiation safety regulation for NORM industries in China also is presented. Contributions to public and workers exposure due to mining of coal and other minerals is presented along with regulatory requirements.

BACKGROUND

In accordance with the Law on Prevention and Control of Radioactive Pollution, the Ministry of Environmental Protection (MEP) in China is responsible for the regulatory control of NORM industries with respect to radiation safety and environmental protection.

Natural radiation exposure levels vary widely across different regions of China. The average annual effective dose to the public from the natural background exposure is about 3.1 mSv/a. Background radiation level associated with human activities is the major contributor to public and occupational exposure. The annual effective doses to the public amount to 0.64 mSv/a from indoor radon exposure and 0.01 mSv/a from coal fired power generation. The use of mineral waste or slag as a building material gives also rise to elevated exposures to indoor exposure.

LEGAL AND REGULATORY FRAMEWORK RELATED TO NORM INDUSTRIES

The Law on Prevention and Control of Radioactive Pollution was established by CPC in 2003 [1]. It is a major law related to nuclear and radiation safety and radiation in the environment. Among others, this law also establishes the basic regulatory principles that are applied to processing NORM. The Law requires that an owner of a non-uranium mine containing elevated levels of radionuclides of natural origin shall conduct an environmental impact assessment and obtain approval and supervision from the local provincial environmental protection agency. Regulation on the safe management of radioactive waste was implemented by the State Council in 2011 in accordance with the above law.

The ‘Chinese BSS’ entitled Basic Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (GB18871-2002) [2] was implemented by the government in 2002. The Chinese BSS clearly defines the human activities involving naturally occurring radioactive material that is not excluded or exempted and that shall be managed in line with the Chinese BSS.

In addition to the above mentioned law, regulation and national standards as well as other regulatory rules or guides were also issued:

(a) Regulations for radioactive waste management (GB14500 – 2002) [3];
(b) Administrative rules on the prevention and control of pollution by tailings;
(c) A list (first batch) of regulations of the radiological environmental impact associated with the exploration and utilization of mineral resources (2013) [4]; and
(d) A requirement for the control of radioactive substances for building material and industrial by-products used in building materials (GB6763-2000).

The list mentioned under (c) is shown in Table 1 and it was published as a notice by MEP in February 2013. The purpose of this notice was to protect the environment and health of the public in accordance with the law on prevention and control of radioactive pollution and the law on assessment of the environmental impact. The scope of this notice applies to NORM industries and includes the exploration and utilization of mineral resources. A very important criterion in this regard is whether or not the activity concentration of any radionuclide of the uranium or thorium decay series exceeds 1 Bq/g in the ore, in intermediate products or in tailings (slag or other residues). The specific regulatory procedure applies to any new project or processing, which falls into the above mentioned scope and for which the activity concentration of 1 Bq/g is exceeded. The operating organization shall prepare two documents, namely a special report describing the assessment of the radiological environmental impact, which is required at the planning stage of the project, and another report related to monitoring and acceptability of the radiological environmental impact during the operation. Both documents shall be submitted to the relevant environmental protection agency for approval.

TABLE 1. LIST (FIRST BATCH) OF REGULATIONS OF RADIOLOGICAL ENVIRONMENTAL IMPACT FOR EXPLORATION AND UTILIZATION OF MINERAL RESOURCES

	Industrial activities
1. Rare earths, including monazite, bastnaesite, xenotime and rare earth clays	Ore mining, ore dressing, smelting
2. Niobium and tantalum	Ore mining, ore dressing, smelting
3. Zirconium and zirconium oxide	Ore mining, ore dressing and smelting of zircon sand and baddeleyite
4. Vanadium	Ore mining and smelting
5. Anthracite	Coal mining and utilization

exposure to natural sources

— Exposures

The normalized collective effective dose from coal fired power plant exhalations to members of the public within 80 km was found to be 16.5 man·Sv/GWa., The corresponding value for a coal gangue power plant was 7000 man·Sv/GWa. The annual collective effective dose to the public arising from buildings using bone coal bricks was 3300 man·Sv/a.

Occupational exposures in mines over the period 1996–2000 are shown in Table 2.

TABLE 2. OCCUPATIONAL EXPOSURES IN MINES

	Annual average number of monitored workers	Annual collective effective dose man·Sv)	Average individual effective dose (mSv/a)
Coal mines	6 500 000	14 600	2.40
Metal mines	1 000 000	5530	5.53
Other mines	3 000 000	2060	0.69
Total or average	10 500 000	22 0000	2.1

Indoor radon concentrations measured in various cities in China during past years are shown in Table 3.

TABLE 3. INDOOR RADON CONCENTRATIONS

	Number of cities	Number of samples	Average radon concentration (Bq/m^3)
Study 1	28		43.8
Study 2	8	2808	34.1
Study 3	9	1994	31.7

Radioactivity levels in various mineral resources and solid residues are shown in Tables 4 and 5, respectively.

TABLE 4. RADIOACTIVITY IN MINERAL RESOURCES

Element or mineral	Activity concentration (Bq/g)						Gamma dose rate (μGy/h)	
	Uranium		Ra-226		Th-232			
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Rare earths	3.972	78	2.529	30.2	5782	137	5.709	32.671
Coal	0.383	167.403	0.212	24.021	0.051	0.910	0.153	2.552
Coal gangue	0.171	1.321	0.118	0.682	0.082	0.241	0.135	0.242

TABLE 5. RADIOACTIVITY IN SOLID MINERAL RESIDUES

Element or mineral	Activity concentration (Bq/g)						Gamma dose rate (μGy/h)	
	Uranium		Ra-226		Th-232			
	Ave.	Max.	Ave.	Max.	Ave.	Max.	Ave.	Max.
Rare earths	2.081	83.044	1.24	53.7	4.8763	85.6	3.249	48.344
Coal	0.225	7.6	0.326	92.178	0.091	0.91	0.162	0.987
Coal gangue	0.191	0.763	0.079	0.415	0.092	0.212	0.115	0.328

There are three main sources of radon emissions from a coal mine: (1) the emissions into the environment by underground ventilation systems; (2) continuous radon release and emanation during the storage period of the raw coal and coal gangue in surface storage sites; and (3) discharge and release of dissolved radon from underground mining water. Radon emissions by coal mine ventilation is the major source. Various types of coal mines in China exhibit additional average annual radon emissions of about 3.24×10^9 Bq/million tons (coal products). Based on the above results, additional radon emissions due to electricity production in typical coal power plants are about 9.72×10^{11} Bq/GWa. Radon release rate from raw coal and coal gangue storage sites ranges from 1 to 40 mBq/ m^2 s, so a typical site area of 5000 m^2, emanates radon in the range of 0.16~6.4 GBq/a. Radon concentrations in the coal mine water vary from of hundreds to 10,000 Bq/m^3. A typical production of 1.9 million t/a of raw coal, discharges about 1.5×10^5 m^3/a of water, which exhale around 0.03~1.5 GBq/a of radon. Table 6 shows additional exposures arising from dwelling in rooms built from coal waste. The annual collective effective dose to the public, arising from buildings using bone-coal bricks is 3,300 man.Sv/a.

TABLE 6. EXPOSURE ARISING FROM BUILDING MATERIAL WITH COAL WASTE AS MAIN COMPONENT

Wall material	Additional internal dose, mSv/a	Additional external dose, mSv/a	Total dose mSv/a
Breeze fixing brick	0.40	0.14	0.54
Entrance brick	0.45	0.04	0.49
Average	0.43	0.10	0.53

The amount of solid waste from rare earths processing is 1.44 million t.

DISCUSSION AND CONCLUSIONS

Exposure to naturally occurring radionuclides as a result of human activities is becoming the major cause of additional exposure to both the public and workers. About 10 million people are working today in mining in China, and 100 million people are living in houses with elevated concentrations of radon.

Exposure to NORM has become a significant issue. It has been shown that the additional dose received by workers from external gamma exposure is 0.69–5.53 mSv/a. If the inhalation of aerosols and dust containing thorium is also considered, the dose will probably exceed 1.0 mSv/a. As for the public, indoor radiation levels are higher in buildings using slag residues. Internal exposure control is quite important. Operational organizations should take measures to reduce the exposure of workers and the government should adopt specific measures to reduce public exposure. Remedial measures should be undertaken in places with high concentrations of indoor radon.

It is necessary to strengthen regulatory control of non-uranium mines. The regulatory authority should develop appropriate regulations and rules and the management system needs to be improved for NORM residues. The Environmental Protection Department should implement measures for regular inspection and supervision of the working sites and the surrounding areas, in order to ensure the safety of the workers and control of waste streams. Radiation safety training courses should be implemented regularly for employees of management and operation departments, in order to improve safety and radiation protection in work practices.

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AIR CREW EXPOSURE TO COSMIC RAYS — CHALLENGES AND MANAGEMENT

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Abstract

Exposures of aircraft crews to cosmic radiation depend not only on the changing geomagnetic shielding along the air routes and the changing solar activity during the solar cycles. They are also influenced by operational factors of airline business, seasonal cycles and economic impacts. Doses to aviation personnel vary with age, professional status and social ties: e.g. younger cabin personnel usually receive higher annual doses than their counterparts. Higher exposed groups experience also larger changes of their annual doses along the solar cycle. The physical, economic and social factors influence the frequency distribution of doses and make it difficult to measure effects of optimization. Optimization of radiation protection for aircraft crews can consider the allocation of crews within the frame of airline business requirements and interests of the personnel. Route calculation programs can include the route dose as an additional optimization factor beside fuel costs and flight time. A global view on the development of aviation business should consider the development of ultra-long distance aircraft and the enormous increase of long-haul routes, in particular across the North Pole. On an international level radiation protection of aircraft crews should seek for cooperation with national and international stakeholder organisations of aviation in order to gain synergetic effects of flight safety and radiation protection. The German central dose registry analysed the official dose monitoring data of all German aircraft crews between 2004 and 2012, i.e., in the decreasing period of solar cycle 23 and the increasing phase of solar cycle 24. The data cover monthly exposures of up to 40,000 pilots and flight attendants.

INTRODUCTION

In Germany, about 40.000 pilots and flight attendants are officially dose monitored. They represent 73% of the collective dose of all occupationally exposed radiation workers in Germany. They also have the highest average annual doses of German radiation workers. The analyses presented here shall shed a light on the dose changes of German aircraft crews between 2004 and 2012, the influence factors and selected types of aviation personnel. In contrast to workplaces e. g. in medicine, industry or nuclear power plants, the possibilities of protection against the high energetic cosmic radiation are very limited. It is not trivial to identify optimization effects among the combined and changing influences of physical and economic factors. Radiation protection measures can focus on work schedule, route planning and pilot decisions en route, but they are not easy to implement. The future development in global aviation will also result in higher exposures. This calls for cooperation of radiation protection specialists with aviation stakeholders, in particular with pilot organizations, in order to gain combined effects between radiation protection, flight safety and the needs of airline business.

PHYSICAL AND ECONOMIC INFLUENCES ON DOSES OF AIRCRAFT CREWS

The impact of cosmic radiation on the ambient dose rate of high altitude radiation, in particular the variable geomagnetic shielding and the temporal changes of the solar activity along the solar cycle phases have been thoroughly studied [1]. The physical factors have a substantial influence on the exposure of aviation personnel on air routes. In order to get a complete picture about the annual doses to aircraft crews, it is also necessary to consider the impact of prioritized route nets, economic and operational factors of the aviation business, route preferences and the allocation of pilots and flight attendants in different phases of their career.

The influence of cosmic radiation on the high altitude radiation in the earth's atmosphere varies with the shielding effect of the solar activity, which again changes periodically in a cycle of more or less eleven years. During the decreasing phase of solar cycle, 23 more galactic radiations could incident on the Earth's atmosphere and increase the ambient dose rate from high altitude radiation. In the beginning of the solar cycle 24 the solar activity rose again and its protective effect against galactic radiation became stronger. The analyses of the exposure of German aircraft crews over years 2004 – 2012 cover most of the decreasing solar activity in solar cycle 23, followed by its rise in the beginning solar cycle 24 in 2009. As expected, the annual doses to German aircraft personnel proceeded anti-cyclically to the solar activity. The solar activity is measured with the relative sunspot index that is based on the number of sunspots [2] (Fig. 1).

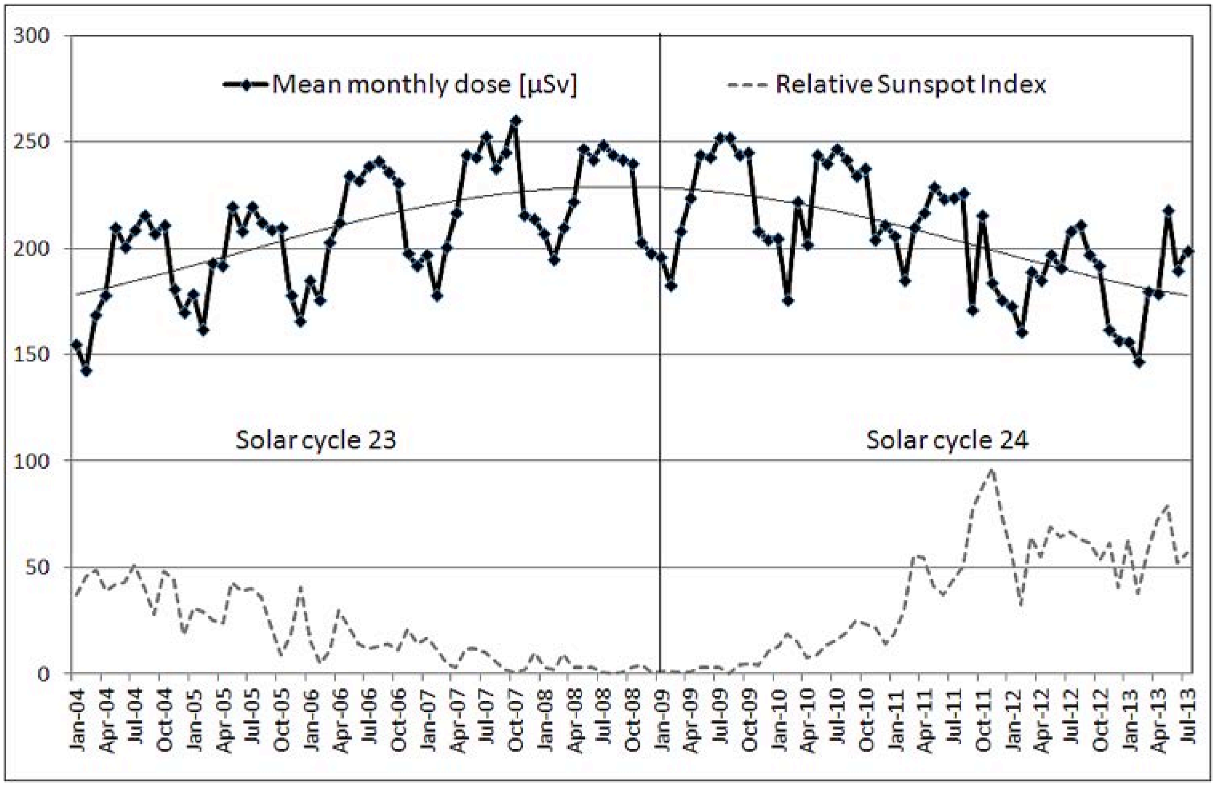

FIG. 1. Influence of solar cycles 23/24 and the seasonal aviation business on doses of German aircrew personnel 2004 - 2013

There is a periodic variation of the average monthly doses to aircrews within each calendar year. This is due to seasonal air trips to holiday destinations. Summertime is always a peak season. Slightly enhanced monthly doses are also observed around Christmas and New Year, albeit to a smaller extent and less regularly. The winter cycles were interrupted by the dull winter business of 2007/08 that followed the beginning of the financial crisis in Sept. 2007. The following years were also rocked by some economic turbulences in the German airline business.

The solar cycle changes doses during various routes. Flights above the latitude 60º N and in particular polar routes are mainly affected because of the low geomagnetic cut-off rigidity that allows more charged particles to be directed along the geomagnetic field lines into the atmosphere. However, route doses on trans-equatorial flights are hardly influenced. They benefit from the increasing geomagnetic shielding in the direction of the equator. For example, during the years 2004 - 2009 the route dose of the polar route flight Frankfurt – New York increased from 50 µSv to 78 µSv whereas the route dose of the trans-equatorial flight Frankfurt – Johannesburg grew only from 24 µSv to 27 µSv [3].

The share of flights on polar routes or other dose-intensive long-haul flights is relatively small. About 80% of all German passenger and cargo aircraft serve the route net on short- and medium range routes, i. e. within Germany, Europe and the Middle East. The individual annual doses to these aircrew personnel vary primarily with the accumulated time spent en route. The admissible annual block time for aircraft crews (time between leaving the parking position and reaching the final parking position at destination) is legally regulated by European and German guidelines and it is limited to 900 hour per year. Within the legal framework exist a wide range of airline specific labour agreements. They compensate stress factors like flight duration, time shift or the different attractiveness of destinations, etc., with leisure time between flights; intercontinental long-haul flights are in particular compensated with rest days after duty. Airline budget serves mainly to short and middle-range destinations within Europe, because short flights with a few time zones to cross require less rest periods and allow more block hours. For these personnel, small route doses may to a certain extent be compensated by higher numbers of executed flights.

FREQUENCY DISTRIBUTION OF DOSES

German air crew personnel consists of 28% of pilots and co-pilots, 69% of flight attendants and pursers and the rest covers technical air force personnel. 58% of all aircrew personnel are women and most of them serve as flight attendants. The frequency distribution of the annual effective doses to female cabin personnel in 2004 indicates two major groups that cluster around normally distributed peaks of 1.3 mSv and 2.5 mSv. Both are surrounded by some minor exposed flight attendants and a small group of higher exposed women [5] (Fig. 2).

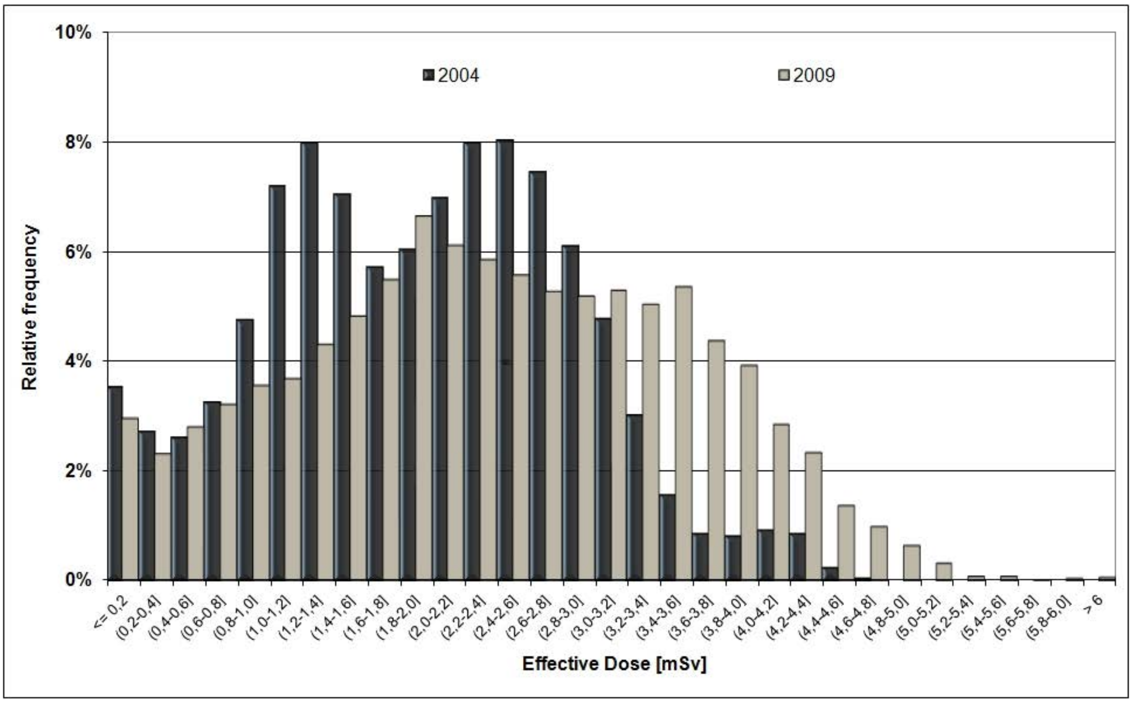

FIG. 2. Relative frequency distribution of effective doses for cabin personnel 2004 and 2009

The frequency distributions also change with the solar cycle. In the consecutive years, until the solar minimum in 2009, the high altitude radiation increased, and the doses drifted year by year towards higher values. The distinct frequency distribution pattern of 2004 moved in the direction of higher doses. The change of the frequency distribution can mainly be described by a multiplicative stretch and less by an additive shift, i.e., those who received higher annual doses, also received a greater dose increments then those with small annual doses. During the following years, when the activity of solar cycle 24 rose again, the frequency distribution drifted back towards its former shape [7].

There is a substantial difference in the frequency distribution of doses between aviation personnel and other radiation exposed workers: are Log-normal frequency distributions of doses are typical for workers exposed in medical, industrial or nuclear work sectors. This results from the multiplicative effect of simultaneous optimization by time, distance and shielding. In aviation however, we usually observe normal frequency distributions because simultaneous protection by time, distance and shielding cannot be applied. The frequency distributions appear as multi-modal, since they are also composed of non-homogeneous groups of aircrew personnel. . It remains a challenge for modelling to identify optimization effects from changes of multi-modal frequency distribution, superposed by the influence of solar cycle and economic factors.

— Selected group typologies

Stratifying the dose distribution of female cabin personal by age classes reveals an interesting typology [8]. Four different groups of flight attendants can be detected around the relative maxima of doses and age.

Part time personnel: A group of the age cohort below 25 years receives small doses below 0.5 mSv. They are presumed to be part-time personnel or seasonal workers. In the peak season's airlines often hire students who work as flight attendants during their semester breaks.

Young globetrotters: At the other end of the dose range is a big group of higher exposed female flight attendants below thirty. Young flight attendants are often socially unattached and take the chance to get to know the world. They absolve many long-distance flights and thus accumulate average annual doses from 2.5 mSv to well over 4 mSv, and the younger they are the higher are their doses.

35+ with social ties: Women in their early thirties are less represented in the cabin. Many have interrupted their job to settle down and have a family. Many women beyond 35 prefer domestic or short- and medium range flights within Europe, which allows them to combine income with family commitment. They form the biggest group and their doses range from 0.6 – 2.0 mSv. When the children grow older, family obligations decrease, and the balance of the family life and work may change again in favour of travelling. This may be an explanation why this group shows a clear tendency to higher doses with an increasing age.

Cabin chiefs: Finally, there is a distinct, small group above 45 years with doses around 2.8 mSv. These women work in a more prominent position as cabin chief in long-range aircrafts.

The stratification of age and doses can also be applied to cockpit personnel and reveals a characteristic age/dose-typology of pilots [9].

CHALLENGES FOR OPTIMIZATION

The challenge of dose optimization represents a combination of dose reduction with the economic needs of aviation business in a highly competitive global economy. Presently, calculation program for the route planning optimize cost, fuel consumption and flight time. It could be possible to also include the route dose as an optimization criterion, in particular at polar routes and in phases of low solar activity. Optimization by work planning would require the allocation of personnel to a route-mix within the frame of the route net requirements. For cabin personnel it is in principle easy because flight attendants can work on both, short and long-range aircraft. However, conflicts may arise with the individual interests of the involved social groups mentioned above. For pilots it would require a multi-type employment for long-haul and short-range mix within the aircraft families. This would involve cost and organisation challenges.

Civil aviation increases globally, in particular on cross-polar routes. There were 402 flight across the North Pole between North America and Asia in 2000; in 2010 the number increased by factor of 24 i.e. 9,658. The development of new ultra-long-range aircraft, i.e., airplanes that allow flying more than 15,000 km and at cruising altitudes of 43,000 feet, may also lead to considerable increments of route doses for the crew. In view of the global development of civil aviation it becomes clear that radiation protection of aircraft crews can only be successful when managed on an international level. The aim should be to seek synergetic effects with other goals in aviation, e.g., flight safety, which can only be achieved in cooperation with national and international stakeholders in aviation.

International Federation of Air Line Pilots Associations (IFALPA) has suggested several measures in their policies for optimization en route that lie within the possibilities and degrees of freedom of the pilots. These measures may involve avoiding of above optimum flight level, avoiding intermediate climbing followed by descent. In these cases it would be helpful to use a dosimeter on board (fixed installed or mobile) that gives an immediate feedback about the changes of the ambient dose rate on route. Pilots favour to have a dosimeter on board as this would allow them not only to optimize doses on route, but to also react immediately on solar particle events due to poor space weather.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 7

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Egypt presents a study that evaluates the occupational and public exposures due to deposition of waste generated from iron and steel industry (iron & steel, coke, chemicals, metal industries). The author draws two scenarios to determine the radiological impact these industries. A scenario taking into account the worker and other individuals involved in the facility, the public, living 100 m of the facility. Radiological assessment is evaluated in both scenarios based on of inhalation, submersion (to dust plume) and external doses, which are compared with the dose limit of 1 mSv/y. Due to the insufficient data required, ingestion dose was not considered for public scenario. In addition, the external radiation dose is not considered in worker scenario due to the limited time of worker's exposure. Both scenarios assume that radionuclides are uniformly distributed in the disposal piles and continuously released in the dust at the disposal area by wind re-suspension. Assessing these scenarios has revealed that occupational exposures are well below the Egyptian regulatory limit. It is important to emphasize the concern for individuals residing in public areas nearby the facility. The estimated doses for this scenario are on the threshold of 1 mSv/y, which has led to investigations and actions aimed at minimizing these doses.

Another very interesting study has arrived from India. It is regarding rare earths production facility. The radiological risk is here arising from thoron and its decay products. The paper presents an evaluation of occupational exposures by workplace monitoring of areas (). This work demonstrates that one can use the monitoring of areas very well for the assessment of occupational exposure and area classification. The results show that the general radiation field in the rare earth production plant is characterized by the dose rate of 0.1 - 10 μGyh^{-1}. The general average background dose rate in the worker-occupied areas was 0.8 μGyh^{-1}. The external dose for an occupational period of 2000 h in a year is estimated to be 1.6 mSv. The average short-lived air activity due to thoron progeny was 40 ± 9 mWL and 0.005 Bqm^{-3} for long lived ^{232}Th. Using those values the estimated internal dose would be 1.425 mSv, and the average individual dose is 3.025 mSv for 2000h working time. The current measurement of the total dose to radiation workers of the facility was found to be only 1.6 mSv with the internal dose contribution of 26%. This is mainly due to the actual occupancy time being only 50% of the estimated time.

Canadian publication describes a methodology developed by Hatch (company name), which can estimate the radionuclides concentrations that are present in various stages of the processing plant that uses materials containing NORM. Knowing the characteristics of the input material, after conducting radio-analysis of samples and evaluating the balance and decay of radionuclides, as well as considering additional physico-chemical features, establishes the behaviour of radionuclides in industrial plant. After a series of calculations and assumptions, the authors claim that it would be possible to predict the most likely to destination of each of the radionuclides present in the raw input material. This would make it possible to determine the magnitude of the probability of finding a radionuclide present in various facility stages (product, by-product, waste). The potential range of radiation emissions from each of the outlet stream can then be estimated and compared to the health and safety exposure limits and guidelines. We can thus estimate the potential radiation exposure at each phase of the operation and provide adequate protection to workers and the environment. Then, using engineering measures, it will be possible to mitigate or eliminate risks which would only be observed during the operation of the plant. This seems to be an interesting approach to the new installation designs, but the methodology can also be applied to existing plants to reduce occupational exposures and activity or amount of radioactive waste.

Another study evaluates occupational exposures of a thermoelectric power plant. The absorbed dose rate and annual effective dose is estimated from the concentrations of uranium, thorium and potassium in the fuel. A series of calculations resulted in annual effective doses ranging from 0.29 to 1.10 mSv/y for indoor occupancy factor of 80%, and annual effective doses ranging from 0.07 to 0,27mSv/y for the outdoor occupancy factor of 20%. The work also reveals that the coal ash in the installation under study, could be used without any kind of control in building/construction. A program or even a macro in excel could be produced so that other thermoelectric power plants could use this methodology.

Two works presented by the same author deal with occupational exposures in a deactivated uranium mine, whose facilities are being used for the processing of monazite and extraction of rare earths. The author focuses on occupational exposures due to two pathways – inhalation of air contaminated by long-lived alpha emitters and external exposure to gamma radiation:

The data refer to periods from 2002–2012 for alpha emitters in the air and 2001–2014 for external exposure to gamma radiation. A series of statistical calculations was applied and dose rates of up to 420 microSv/h were obtained in the case of gamma radiation. Activity concentration of long-lived alpha emitters reached up to 37 Bq / m^3, which, according to the author exceeds 100 times the annual limit. It can be seen that training, qualification of workers, in addition to good supervision may well control occupational exposures. I would like to draw attention to the isolated use of the gamma dose rate in decision-making regarding intervention actions. A broader approach should be used for the workplace analysis and for a more correct decision-making.

CHAIRS' SUMMARY OF TOPICAL SESSION 7

A variety of industrial applications utilize materials of geological origin, and these contain naturally occurring radioactive materials (NORM), either at their original concentration or inadvertently enhanced through industrial processes. Working with NORM can produce occupational radiation exposures, as well as public exposures, i.e. from the use, reuse, and disposal of NORM residues. There has been an increasing awareness in recent years that such exposures can be significant, and that a graded approach to radiation protection control is required.

The session opened with a keynote presentation from Professor Garcia-Tenorio, who pointed out the challenges involved in implementing regulations of NORM industries. This traced the evolution of this subject, starting from the 1996 IAEA International Basic Safety Standards, through the series of international NORM conferences, up to the revised IAEA BSS (GSR Part 3) in 2014 and beyond. While there has clearly been much debate (and even confusion) about how to apply a graded approach, it is hoped that the revised BSS will provide greater clarity as to how the system of protection should be applied to NORM. Even so, it was suggested that there is still scope for misunderstanding or misapplying concepts such as reference levels. I was also noted that there is not yet enough evidence of the practical application of optimization, i.e. a principle that applies to all exposure situations.

Topical presentations were given on occupational radiation protection in the oil and gas industry in Brazil, and the regulatory challenges in China, which has a large number of NORM industries and millions of potentially exposed workers. There were six papers covering metal smelting (Egypt), rare earth production (India), NORM processing industries (Canada), coal-fired power plants (India), and uranium mining and processing of monazite (Brazil).

The main outcomes which have arisen from the session were:

- The main industries involving occupational radiation exposures from NORM have now been identified and characterized, but there is still a need to implement a graded and proportionate system of control.
- Exposures to NORM can contain characteristics of both existing and planned exposure situations, and debates about the most appropriate form of control have caused confusion and delay. However, it is now being understood that graded controls are required for both types of the exposure situation.
- There is a need to consider the application of optimization in practice. This requires realistic dose estimates for NORM workers using workplace monitoring rather than models that often significantly overestimate exposures.
- More guidance is required on the derivation and use of dose constraints and reference levels. This should show how these concepts can be applied to NORM industries in practice.
- NORM industries are diverse and present a wide range of radiological characteristics. Consequently, an industry-specific approach is essential.
- More emphasis is still needed on radiation protection awareness in NORM industries, and the training of NORM workers.
- The management of NORM residues and waste, including the remediation of contaminated sites, is one of the main challenges, which involves occupational and public exposures. Some NORM residues are produced in extremely large quantities

and there is increasing emphasis on the re-use and recycling of these materials - processes that will also require a graded approach to radiation protection control.

The session included a topical presentation from Germany on air crew exposure to cosmic rays, which generated a lot of discussion. Such exposures can now be well characterized through a knowledge of flight patterns. The results indicate that individual and (especially) collective occupational exposures can be significant. This has been known for some time, but it has been noted that there is now a significant upward trend in occupational exposures due to changes in the way the commercial aviation industry operates. The scope for optimizing such exposures has always been limited; however, the presentation indicated that there are protection options in terms of flight planning and operation and that these are worthy of further examination and an on-going dialogue with the airline industry.

TOPICAL SESSION 8:

OCCUPATIONAL RADIATION PROTECTION IN THE WORKPLACES INVOLVING EXPOSURE TO RADON

Chairpersons: J. Takala, Canada and Senlin Liu, China

OVERVIEW OF OCCUPATIONAL RADON EXPOSURE — PAST, PRESENT AND FUTURE

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Abstract

All soils and rocks contain natural levels of uranium-238 and its decay product, radium-226 which is the parent of radon-222 (radon). Since radon is a noble gas, some portion of the radon produced through the decay of radium-226 will escape from the soil or rocks where it is formed and migrate through pore space in soil or fractures in rock, either as a gas or dissolved in water, and subsequently may enter mines or underground workplaces. Epidemiology studies of underground miners, and more recently residential radon, have demonstrated that exposure to radon and its progeny can cause lung cancer. This paper discusses how the regulation of workers exposure to radon in mines and the exposures of miners to radon and progeny (radon) have changed since the widespread recognition of radon as a health hazard in the 1950's. Radon levels in non-mine workplaces is also discussed.

INTRODUCTION – WORKERS HAVE BEEN EXPOSED TO RADON AND PROGENY FOR CENTURIES

Mining of metals and minerals has been taking place for thousands of years, with the Egyptians mining gold as long as 4,000 years ago. With the fall of the Roman Empire in the 5th century, mining activity decreased substantially due to the instability in Western Europe until the 11th century or so when metal mining activities increased. In 1168, silver was discovered near the town of Freiberg in Saxony and in the 15th century a large silver deposit was discovered at Joachimsthal in Bohemia which was the basis for Agricola's treatise on mining De Re Metallica. Even as early as Agricola, there was a recognition of an unusually high incidence of a fatal lung disease in miners [1,2]. Both of these areas eventually were later mined for uranium. The unusual, lung disease was eventually recognized as lung cancer which was reported to have caused up to 70% of the miners' deaths [e.g., 3,4]. According to materials cited in [5], the Schneeberg mine was thought to have had radon progeny levels ranging from 30 to 150 WL.

By the mid 1950's, there was a global awareness of the risk of lung cancer in miners. This drove the development of radiation protection guidelines for radon and consequent parallel changes to mining methods and ventilation practices which resulted in substantial improvements in radon levels in uranium mines [e.g., 5,6,8].

Although much of the radon literature addresses exposures to radon in underground mining, especially uranium mining, all natural materials contain some level of radium-226. Thus, the potential for exposure to elevated radon levels in workplaces is not limited to the mining and processing of uranium. Examples include the mining and processing of various minerals, among them, tin, tantalum, niobium, rare earths, aluminium, some copper and gold occurrences and phosphate rock, along with below ground workplaces tunnels, tourist caves and radon spas. [9,10]

The following sections of this paper discuss the evolution of radiation protection guidance for radon and the levels of radon in underground mines and other workplaces

WORKPLACE RADIATION STANDARDS FOR RADON OVER TIME

Traditionally, the International Commission on Radiological Protection (ICRP) provides international guidance on radiation protection and has had an interest in radon for many years. As early as 1972, the ICRP in Report 24 described the principles for radiation protection of (uranium) miners. Although the focus of ICRP 24 is uranium mining, the ICRP notes that radium-226 is a member of the uranium decay chain "which is found almost everywhere" and hence, (elevated) "radon is not limited to uranium mines." ICRP 24, noting the rapid development of radon epidemiology, suggested an annual limit of 12 WLM. Since then, the ICRP continued to evaluate the effects of exposure to radon and in ICRP 65 [12] recommended an annual limit of 4 WLM. Most recently, the ICRP recommended a doubling of its nominal risk coefficient for radon-induced lung cancer based on its review of uranium miner epidemiology [13] If the ICRP recommendations were to be "simplistically" applied directly to radiation protection limits, this would suggest a reduction from the current 4 WLM per year limit [12] to 2 WLM per year. Current ICRP activities concerning radon are described in [14].

As suggested earlier, radiation protection standards for exposure to radon developed rapidly following the world-wide recognition of radon in mines as a health hazard. Although the details varied by country, the experience in the USA is illustrative of the evolution of radiation protection guidance against radon. The United States uranium industry began after World War II when the government began to buy uranium. Early mine operators knew nothing of the hazard of exposure to radon and no government agency had the authority to regulate the health and safety of miners. Beginning in 1954, the U.S. Atomic Energy Commission had regulatory authority over the uranium industry after the material was mined but had no authority to regulate the mining industry. There were no mining industry standards and no personnel experienced in assessing the hazard within the mining community. [5,6] By 1949, the U.S. Public Health Service (USPHS) became concerned about the potential hazard based on the experience of miners in the Joachimsthal/Schneeberg mines and made measurements in about 40 mines in Utah and Colorado and found high concentrations of radon averaging over 92,000 Bq m^{-3} (2,500 pCi L^{-1}) [15].

By 1955, the USPHS developed the concept of expressing a tolerance level in terms of the potential alpha energy of radon decay products in air. In 1958, the Nuclear Standards Board of the American National Standards Association (later Institute - ANSI), established a committee to develop a standard for uranium mines and mills. This standard was adopted in 1960 and was denoted the working level (WL). The adoption of 1 WL per month or 12 WLM per year as a standard drove the improvements for a significant decrease in miner exposures beginning in 1960. The US standard was reduced to 4 WLM/year in 1971 as the emerging picture of lung cancer developed. This standard is still in effect in mines in the United States; however, an ANSI committee is currently evaluating radiological protection of workers in mines, including exposure to radon [5 8,15,16].

EXPOSURES TO RADON AND PROGENY IN MINES

As previously indicated, exposure of miners to elevated radon concentrations is not limited to uranium mines, and miner epidemiology includes studies of not only uranium miners but also fluorspar, iron and gold miners, amongst others. The exposures of miners in uranium, iron and fluorspar mines is well described in [5,9,13, 18,19] through a synthesis of numerous publications.

In the early days of uranium mining, the exposures of miners could be quite high with WL values of 100 or more. Since the 1950's there has been very large (orders of magnitude) reductions in exposures to radon in mines. The Canadian experience in western Canadian uranium mines provides an example of this dramatic reduction in workplace exposure levels.

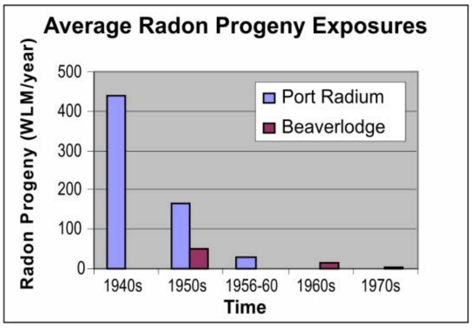

Fig. 1 Radon pogengy level during 1940s ~1970s

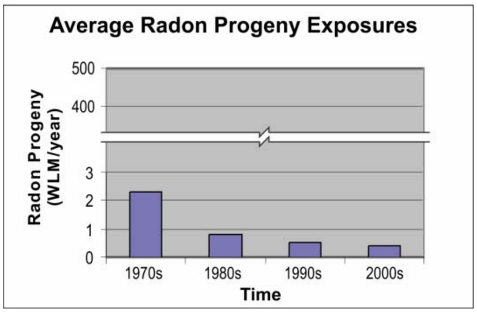

Fig. 2 Radon pogengy level during 1970s ~2000s

Port Radium was the first mine in Canada where radon/radon decay product sampling was performed, with the first samples being taken in 1945. According to [17], the very first radon samples to be taken in Canada were taken at Port Radium in February 1945. (Apparently, the reasons for the study was to investigate "suffocating gas" noticed by the miners. The suffocating gas turned out to be straight oxygen deficiency. The first mechanical ventilation was introduced in 1949 in this mine.) This study reported radon levels ranging from 13,000 to 47,000 pC/L). Eldorado's Beaverlodge mine began operation in 1949 and closed in 1981. As illustrated in Figure 1 and Figure 2, there was great improvement in exposures in these mines from the 1940's through 1960's. This improvement continued over time as newer Saskatchewan mines were opened during the 1970's. Miner exposures in modern Saskatchewan mines is less than 1 WLM per year.

EXPOSURES TO RADON AND PROGENY IN NON-MINE WORKPLACES

All soils and rock contain naturally occurring radioactive materials (NORM) and thus many ores and raw materials contain relatively elevated levels of natural radionuclides. Examples of such NORM materials include uranium ores, monazite (a source of rare earth minerals), and phosphate rock used to produce phosphate fertilizer. In addition to the mining and processing of NORM material, elevated radon levels may also occur. Underground workplaces such as basements mines, caves and utility industry service ducts will have radon and, in some cases, significant levels of radon. In addition, some proportion of above-ground workplaces in radon affected areas may also experience elevated levels of radon although especially in use cellars, basements and poorly ventilated ground floor rooms.

According to [10], by far the largest category of workers exposed to ionizing radiation are those employed in the extractive and processing industries. According to [10], a survey of six underground coal mines in Pakistan reported radon concentration. A study of radiation levels in China [21] reports average radon concentrations of up to 1,200 Bq/m^3 in coal mines. According to [10], an occupational exposure survey in over 500 of the 2,600 water supply facilities in Bavaria showed that, in all geological regions, exposure levels giving rise to over 6 mSv/a can occur. Radon measurements in Irish schools has been conducted since 1998, with a total of 45,000 individual radon measurements made in 3,444 primary and post-primary schools. The average radon concentration was 93 Bq/m^3, the highest concentration measured was 4,948 Bq/m^3.

Radon dissolved in water is an important source of radon in mines and workplaces According to [22], the average concentration of radon in groundwater is of the order of 10 Bq/m^3 but can be very much higher in groundwater in mineralized areas. For example, water from natural springs in regions with radium-226 levels of up to 1500 kBq/L was associated with indoor radon levels above 2000 Bq/m^3.

The International Atomic Energy Agency has recognized the potential for elevated radon levels in workplaces with the mines [19] and has prepared radiation protection for such situations [20].

DISCUSSION

It is clear that since the recognition of radon as an occupational health hazard in the 1950's, there have been very large reductions in the exposures of uranium miners to radon and that the application of good engineering, good work practices and ALARA continues to ensure that workplace exposures are well below the current limit of 4 WLM per annum. In addition to uranium mines, radon is also present in many other mines and workplaces. Radon levels vary widely by region, mineralogy and work practice. However, radiation protection guidance for radon has been developed by international and national authorities to ensure safe workplaces. Radon levels in modern uranium mines are very low, typically well below the current limit of 4 WLM per year. With the continued application of ALARA and good work practice will continue to ensure safe levels of workplace radon in uranium mines; however, it will be important in the future to ensure that the same radiation protection principles are applied to none-uranium mines and workplaces. A recent report of the ICRP [23] provides a coherent system of protection against radon that is applicable to all sources and situations.

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CHALLENGES AND IMPLEMENTATION FROM A REGULATORY PERSPECTIVE — SOUTH AFRICA SPECIAL CASE MINES

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Abstract

South Africa is rich in metals such as gold and limited reserves of uranium. The mining of the metals brings the disturbance of the solid quartz pebble conglomerate (QPC) which makes up the ore bodies. Gold and uranium deposits largely coexist in the QPCs and mining for either will release radioactive contaminants associated with uranium's progeny; radon in particular. The grades of uranium in the ore are not high, but the potential exist for radon levels to build up to significant concentrations. The ore bodies had been largely exploited since the 1950s for its gold and uranium content, and this exploitation opened up large areas that are available for radon to emanate from. Safety assessments showed that workers in these mines were exposed to varying levels of radon. Since underground mines depend on forced ventilation and the dynamic nature of mining, the extent of radon contamination is vast in some mines. Increased exposures to radon necessitated that more stringent regulatory controls were exercised. The mines with high levels of radon were classified as Special Case Mines (SCM). This paper will investigate the challenges faced from a regulatory perspective in dealing with SCMs and the outcomes of the implementation process.

INTRODUCTION

The handling and processing of radioactive material in South Africa is regulated by 2 acts of Parliament namely the National Nuclear Regulator Act (NNRA) 47 of 1999 [1] and the Hazardous Substances Act 15 of 1973 [2]. Regulations for both these Acts were published within South Africa. This paper will focus on the scope of the NNRA with its associated regulations published as Safety Standards and Regulatory Practices (SSRP) [3]. The SSRP listed the details of exclusions, exemption, registration and licensing regarding the scope allowed under these regulations. Detailed requirements are also spelled out for authorised holders, but one of the main components of the regulations is dose limitation. The SSRP states that the occupational exposure of any worker shall be so controlled that an average effective dose of 20 mSv/a averaged over 5 consecutive years are not exceeded, as well as a maximum of 50 mSv/a in any single year. However, the Mining and Minerals Processing of Naturally Occurring Radioactive Material (NORM) was not regulated in South Africa since 1990 after the Council for Nuclear Safety (CNS) was established in 1988. The CNS was the precursor to the National Nuclear Regulator as the national competent authority on nuclear safety.

Due to circumstances and the levels of radiation that mine workers were exposed to, an additional requirement was added to the SSRP to accommodate the mines with higher radiation readings to get in line with best practices and minimising effective doses. It states that in special circumstances, provided that radiation protection in the action has been optimised (as required), but occupational exposures still remain above the dose limit (50 mSv/a), the Regulator may approve a temporary change in the dose limit provided that all reasonable efforts are being made to improve the working conditions to the point where compliance with the dose limits can be achieved. This temporary change shall not exceed 5 years and shall not be renewed. The International Atomic Energy Agency (IAEA) published the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources Safety Series No. 115 [4], which influenced the drafting of the South African Regulations (SSRP). However, with time having passed and gaps that have been identified in the legislation, it became clear that the South African Regulations must be revised to include more stringent requirements to minimise occupational exposure.

MINING AND MINERAL PROCESSING

The dose limits as introduced in the previous section are applicable to all occupational exposure in South Africa. These would apply to nuclear power reactors, research reactors and mining and minerals processing. Over the years, the highest published effective doses experienced for workers were in the NORM industry [5], i.e., mining of gold. It was established that the primary radiation exposure pathway in gold and uranium underground workings arose from 222Rn and its particulate progeny inhalation.

The reasons for the higher occupational exposures could be attributed to the types of reefs that are mined. Mining is very dynamic in nature because of the harsh environment and depths at which it takes place together with extensive networks of underground haulages and cross cuts. The uranium grades in the ore is important as various reefs will have differing grades of uranium content and hence the source material for radon and its progeny. The biggest contributor to higher radon doses arises from inefficient ventilation controls as forced ventilation systems are used to introduce fresh air to workings underground and systems to remove the contaminated (radon-laden) air. Coupled with increased production pressures, older worked-out areas are often opened, and hence unexpected consequences arise, i.e. the surfaces from which radon exhalations are significantly increased. The result is that ventilation systems not equipped to handle the removal of the radon-laden air efficiently cause the air to be circulated in the mine and often increase effective doses.

SPECIAL CASE MINES (SCM)

Radiological exposure and radioactive material were not regulated in the NORM industry in South Africa before the CNS was established (1988). As discussed in previous sections, large areas had been mined already by this time and when proper controls for safety assessments and monitoring programmes were introduced in the industry [6], it became alarmingly clear that it would be a challenge for mines to comply with the required dose limits at the time. Radon dose conversion conventions had been conservatively applied at the time and this contributed to the higher doses recorded.

It became clear that for workers at a SCM, there was the potential for radiological exposure of 1.7 mSv/month or above and that the projected annual effective dose exceeded 20 mSv if the worker continued to work in the area under the same conditions. The main cause was due to inhalation of radon and its progeny. The regulator's (NNR) response had then been consistent with the following instructions to the mines:

- Identify all working areas where workers could be exposed to doses above the dose limit;

- Identify all persons who could be approaching and/or exceeding the dose limit;
- Immediately remove all workers whose annual projected doses exceed the 50 mSv/a;
- Supply the NNR with mechanisms by which compliance with occupational radiation dose limits would be achieved.

The authorised holders' (mines) remedial plans would include the following:

- Engineering controls planned to prevent contaminated (used) air to be recirculated in mine;
- Plans would also typically include a long term view of the ventilation of the underground workings for:
- Installation of ventilation control systems in stopes;
- Installation and operation of booster fans;
- Removal of obstructions in working places that causes low air velocities;
- Dedicated return airways for air from working places with elevated ^{222}Rn levels;
- Planned velocities for stopping panels – goals/targets, and
- A sealing programme including a time schedule for the sealing of all old working areas to prevent air contaminated with ^{222}Rn entering current working areas and introduction of fresh air into problem areas [7].

IMPROVEMENTS AND CHALLENGES

The previous sections highlighted the problem of high effective doses from radon experienced in some South African gold and uranium mines. The possible reasons were discussed for the situation and the responses to the challenges from a regulatory perspective, but also from the reactions of the operators in achieving compliance to the legislation. Key focus was then directed at the identified Special Case Mines to find ways to minimise the exposures. The extent of the problem was investigated first. After extensive surveys and assessments that identified key areas, it was decided to have working group meetings that included key role players in the industry to tackle the challenges. These role players included the mines, organised labour, the regulators and key Radiation Protection Specialists. The working group meetings' main focus was on investigating methods of reducing the exposures to radon through optimisation of the ventilation systems.

The probable solutions from the working group meetings included sealing programmes:

- Older mined-out areas shall be effectively sealed of;
- Ventilation and radiation protection staff shall be actively involved in day-to-day management of systems that could influence the workers' doses; and
- Adequate staffing and financial resource shall be allocated in order to effectively implement mitigation strategies and monitoring programmes.

There were challenges during the implementation of the programmes, but to a large extent, the strategies worked and the worker doses became more controlled below the annual dose limits. A significant increase in inspections by the Regulator at the Special Case Mines also kept track of the worker doses. It was reported that during the 2003/2004 financial year, a total of 324 workers exceeded the 50 mSv/a effective dose limit [5]. The situation can now be reported that zero (0) workers have exceeded the dose limit in the last reported financial year [8]. It can also be reported that all workers are below the annual average of 20 mSv/a as discussed in the Introduction. There are, however, still 7 mines classified as Special Case Mines and efforts are ongoing to remove these mines from the list through persistent efforts from the Regulator and the operators.

The progress made in the NORM industry with particular focus on underground gold and uranium mining is a testament to cooperation between the authorities and operators, but the process did not come without challenges. The following on-going problems are noted:

a) There are still workers in the 20 to <50 mSv/a exposure grouping(s).
b) Some ventilation systems are not fully optimised.
c) Strategies for sealing programmes have not been fully realised.
d) Integrated Time and Attendance (T&A) Systems not adopted by all stakeholders.
e) A great number of the workforce makes up "Roaming"; workers who are deployed on levels in shafts with varying degrees of ^{222}Rn levels.
f) Timeously identification of work areas/levels with high ^{222}Rn activity concentrations.
g) Implementation of Worker Radiation Protection Programmes.

Further challenges that have been identified for the near future include the adoption of updated radon and thoron dose conversion factors (DCF) [9]. The regulations are currently being revised and the discussions surrounding the adoption of the radon dose conversions are in effect. The more conservative nature of the recommended dose conversion factors could result in more mines being classified as Special Case Mines.

CONCLUSION

The occupational exposure of workers is paramount, but due to circumstances and the environment that the workers are employed in, a balance between the risks and the benefit are always drawn. However, the workers must be protected and therefore compliance to the legislation must follow explicitly. In areas where cooperation between the industry and the authorities would lead to mutual benefits, i.e. keeping worker doses as low as reasonably achievable and compliance to legislation on the other hand, it must be encouraged to find common solutions. Careful consideration must be given to the updated radon dose conversion factors as the implication for the industry is obvious.

The need for adequate protection from complex exposure scenarios in the workplace brought significant challenges to the fore. The need to mine and produce more product (e.g. Au, U, etc.) enhances the risks to the workers, but with robust regulatory tools and programmes at hand, occupational exposures can be controlled. The responses to the challenges are measured through regulatory inspections and audits commensurate with the exposures at the facility. In cases where non-compliance to the legislation cannot be achieved, more stringent enforcement activities are enacted. The off-set for the cost and effort that go into the implementation of the optimisation and mitigation measures are ultimately seen in the decreased worker exposures. The process of finding workable solutions to the challenges also highlights the role of the Regulator and the role of the operator, but again a key balance is struck as it is the operator's responsibility to protect its workers. The one key aspect to finding the solution to the challenge is the appropriate response in legislative revisions that should be brought about where gaps exist. Lastly, as is true for the operator, continual improvement in management and reporting systems for the Regulator, would also apply in dealing with challenges and the implementation of its mandate.

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PRACTICAL IMPLEMENTATION OF ANTICIPATED RADON DOSIMETRY CHANGES IN THE MINING INDUSTRY

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Abstract

The anticipated increase, roughly double, of the dose conversion factor for radon and radon decay products will require a review of the optimization of protection for mining operations where exposure to radon occurs. Some of the potential consequences and possible solutions are briefly discussed.

INTRODUCTION – WHAT ARE THE ANTICIPATED CHANGES?

In 2009, the International Commission on Radiological Protection (ICRP) approved a Statement on Radon [1] following a review of the scientific information available on the risk of health effects attributable to radon (^{222}Rn). The Statement included the revision of the Commission's recommended nominal risk coefficient for a population of all ages to 8 x 10^{-10} per (Bq h m^{-3}) for exposure to radon in equilibrium with its short-lived decay products. The Commission did not recommend a different coefficient for adults or workers. The new value is 1.8 times the risk coefficient of 8 x 10^{-5} per (mJ h m^{-3}) previously recommended in the ICRP Publication 65 [2] after conversion to radon concentration. In 2007, in the ICRP Publication 103 [3], the nominal risk coefficient for effective dose for adults was revised from 5.6 x 10^{-5} per mSv [4] to 4.2 x 10^{-5} per mSv, indicating a decrease by a factor of 0.75. The implication of these changes is that the dose conversion convention previously recommended by the ICRP for workers [2] would increase by a factor of 1.8/0.75 = 2.4, i.e., from 1.4 mSv per (mJ h m^{-3}) to 3.4 mSv per (mJ h m^{-3}).

However, the Statement on Radon also foreshadowed the intention of the Commission to move from a dose conversion convention, based on epidemiological data, to a dose coefficient derived from dosimetric modelling of the intake, deposition and decay of radon decay products in the lung, and no new dose conversion convention has been recommended. To date (December 2014) a nominal dose coefficient for radon has not yet been recommended either, but a draft publication on occupational intakes of radionuclides was released for public comment in 2012 [5], in which the values of 3.0 mSv per (mJ h m^{-3}) for mines and 5.9 mSv per (mJ h m^{-3}) for indoor workplaces were proposed. For mining environments, both the dose conversion convention and dosimetric modelling approaches imply an increase in estimated effective doses by a factor of a little over 2 for a given exposure. For the purpose of the following, the term 'dose conversion factor' (DCF) is used to accommodate either approach.

CONSEQUENCES IN REGULATED MINES

For mines already subject to regulatory control of exposure to radiation, and in which exposure to radon or radon decay products is taken into account, the anticipated dosimetric change implies a need to:

- Assess effective doses using a new DCF;
- Review the adequacy of the dose assessment program;

- Review the optimization of protection of the workforce; and
- If necessary, take action to reduce the exposure.

— Dose assessment

Monitoring and dose assessment programs for radon and radon decay products are designed to estimate effective doses as accurately as necessary in the given circumstances. For mine workers who may regularly receive doses that amount a significant fraction of the dose limit, personal monitoring is likely to be necessary, or at least a comprehensive program of the workplace monitoring and recording of time-in-location for groups of similarly exposed workers. For less exposed workers, representative assessments for the work group may be adequate. The new DCF may require the transition of some work groups to the more intensive monitoring methodology.

Improvements in individual dose assessment may also reveal that conservative assumptions adopted for less intensive monitoring programs are unnecessary, resulting in assessed doses that would be insignificantly changed by the introduction of a new DCF. This has been the experience in at least one uranium mine [6].

Depending on the final recommendations of ICRP, it may be necessary to consider more detailed characterization of mine atmospheres, in particular for the particle size distribution of radon decay products [7-9]. However, it appears likely that the ICRP will recommend the use of default values unless exposure conditions vary significantly from the assumptions made for the recommended DCF. Measuring airborne particle sizes in a mine environment is difficult and equipment for assessing activity concentration of radon progeny by particle size is scarce.

Dose records, both old and new, will need to include information regarding the DCF used, in order to be meaningful for any future evaluation.

— Optimization of protection

(a) Discourage smoking

From a worker's health perspective, one strategy for potentially significant reduction in risk from radon is to persuade smokers in the workforce to stop smoking. Whatever the exposure to radon, the risk for regular smokers of more than about 25 cigarettes per day is much greater than that for never smokers – some 25 to 30 times greater in homes [10] but perhaps rather less than that in mine environments [11]. While this would only benefit those individual workers who quit smoking, it would also substantially reduce the statistical risk from radon averaged over the workgroup as a whole.

(b) Assess the need for measures to reduce exposure

The increase of the assessed dose for a given exposure implies a need to reassess the optimization process from which the protective measures in the mine have been derived. If all doses are shifted upwards by a factor of about 2, one or more of the following measures may need to be considered.

(c) Improve ventilation in underground mines

The primary way of reducing the exposure to radon in underground mines lays in an improved ventilation. Changes to ventilation rates need to be considered in the context of optimization as, apart from cost, higher air velocities may create other problems such as increased dusting, associated with higher doses due to dust inhalation and, possibly, impaired visibility. Greater quantities of fresh air may also alter the particle size characteristics of mine air which, in some circumstances, could counter the benefit lower air concentrations due to an increase of the modelled dose per unit exposure [7].

(d) Control sources where possible

It can be difficult to control sources of exposure in the mining environments, where the material mined, or the host rock from which it is extracted, is the source. In some circumstances, however, a degree of control may be possible. For example, if radon-rich water is present in the mine, diversion or dewatering may reduce the exhalation of radon from that source. In some underground mines, ‘shotcrete’ (a sprayable fibre-impregnated concrete) is used to stabilize excavated surfaces and may partially curtail radon exhalation, although there is a paucity of information in the literature on its effectiveness.

(e) Apply engineering controls; and include them in dose assessment

In many mine environments, the work involves operation of stationary or mobile equipment driven from enclosed and air-conditioned cabins. Filtration of the indrawn air will reduce radon decay product concentrations, but not those of radon itself. In typical mine environments, this would normally result in a net reduction in exposure, but in exceptional circumstances – such as long uninterrupted periods of filtered air supply – consideration may need to be given to the possibility of changes in the modelled DCF due to changes in particle size distribution [7]. Dose assessment should, as far as possible, be based on actual exposures, for example through personal monitoring or through air sampling within the cabin.

Mining operations where radon levels are high, such as uranium mines with a high ore grade or very deep underground mines, where ventilation cannot be substantially improved without unwanted consequences, may need to consider or upgrade the use of automation and robotics technologies to avoid worker’s exposure.

(f) Apply administrative measures

Administrative measures for controlling exposure may need to be reviewed. For example, where reference levels of radon or progeny concentration are used to indicate the safety status of a mine, the need to vacate an area in the event of a ventilation failure underground (or atmospheric inversion conditions in an open pit) can be introduced. The numerical values of the reference levels should be reassessed as part of the review of protection optimization. Optimization will need to balance the possible temporary nature of high radon concentrations against the cost of disruption of work. Job rotation to reduce individual doses should be considered only as a last resort, and with the approval of the regulatory body.

(g) Use personal protective equipment where appropriate

While the use of personal protective equipment, such as respirators or filtered-air helmets is considered only after engineering and administrative solutions have been employed to reduce exposure, there may be situations, such as temporary high radon concentrations, in which the use of such equipment is appropriate.

POSSIBLE CONSEQUENCES FOR MINES THAT ARE CURRENTLY NOT REGULATED

Mining operations that are not regulated for control of radiation as planned exposure situations, are treated as existing exposure situations [3,12]. However, if the change to the DCF for radon results in a decrease of the reference level for radon, and if concentrations remain above this value, the requirements for planned exposure situations may need to be applied. The regulatory authority will set the reference level at a value that does not exceed 1000 Bq m^{-3} [12]. The IAEA has published useful guidance on the need for radiation protection in work involving mining and processing of minerals and raw materials [13] that can be adapted for specific circumstances.

SUMMARY

The anticipated increase of the DCF for radon and its progeny requires a review of optimization of protection in mines where radon exposure occurs. Some mining operations currently treated as existing exposure situations may be re-classified as planned exposure situations and become subject to stricter regulatory oversight. Mining operations already regulated as planned exposure situations will need to assess the need for changes in dose assessment program and in the radiation management program. In most cases it would be expected that minor improvements in these programs will be adequate for demonstrating that protection remains optimized, but in some situations, especially for mines where current radon exposures are high, significant effort to reduce exposure may be required.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 8

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There was one paper provided for Session 8 (Radon Dosimetry). The paper was entitled "The Implications of the Proposed Changes in Radon Dosimetry to the Uranium Industry" by Frank Harris of Rio Tinto, Australia.

The paper described two focuses associated with the change in radon exposure assessment: the approximate doubling of the risk factor and the influence of physical properties of the radon decay products on the dosimetry. The uranium industry has already responded with a range of initiatives to both, improved assessment of radon dose and implementation of new practices to mitigate the risk. The uranium industry is also actively working with the regulatory and other bodies to re-examine the physical properties of radon decay products in the context of modern mining technology. The use of new mitigation techniques and improvements in radon monitoring and characterisation will be applied to maintain the current approach for dose optimisation in uranium operations.

CHAIRS' SUMMARY OF TOPICAL SESSION 8

The keynote address by Dr. Douglas Chambers from Canada gave a broad overview of the evolution of the history of radiation protection standards to radon and its progeny. It was noted that radon in workplaces varies widely with geology and work practices. With increasing knowledge of radon and its health impacts the regulatory standards and work practices have evolved with time. Data was presented that showed a decrease in workers' exposures by several orders of magnitude in the Canadian underground uranium mines from the 1940's to 1970's with an ongoing downward trend since then. The current situation in modern uranium mines is that radon levels are low and well controlled in most circumstances. Data presented from the situation in South Africa supported overall trend of improving exposures and showed that all workers are now meeting the dose limits, notwithstanding the ongoing efforts required to achieve these results. Finally, it is noted that it will be important to apply radiation protection principles to non-uranium mines and workplaces in future.

A presentation by Dr. John Hunt from England was given on new developments from the ICRP recommendations regarding radon exposure. ICRP publication 115 was reviewed and showed how the analysis of the epidemiological data had led to an approximate doubling of the nominal risk coefficient. The dosimetric approach to radon risk was reviewed, including a number of the key parameters. The ICRP's preliminary dose coefficients as calculated by the dosimetric approach were presented for the nominal home, indoor workplace, and mine environments. The calculated risks from the epidemiological studies and dosimetric approach show reasonable agreement with each other. The integrated and graded approach for the management of radon exposure, as given in the ICRP publication 126, was also reviewed. Finally, it was noted that the ICRP will publish new reference dose coefficients for the inhalation and ingestion of radon and its progeny.

The presentation of the new developments from the ICRP set the stage for some of the practical challenges from a regulatory and industry perspective. The presentation from South Africa highlighted the considerable efforts that have been undertaken over the last two decades to control and reduce radon progeny exposures in many underground mines. With a potential doubling of the calculated doses from radon progeny and with the new dose conversion factors from the ICRP, past optimization efforts will need to be re-examined. Work in this area should include improved monitoring, better ventilation, more effective control of radon sources, use of more rigorous administrative controls, and use of personal protective equipment. The potential doubling of doses from radon will also likely raise some concerns and the challenge of communicating the new radon risk information to the concerned stakeholders.

The elevated risk to radon from smoking was noted. Discouraging a workforce from smoking could have substantial health benefits and substantially reduce their risk from radon exposure. In the area of gaps, with regard to the dosimetric approach of the ICRP, there is a lack of monitoring equipment and techniques, along with little current data on the required parameters in modern work environments. More work is needed in all these areas before the ICRP dosimetric approach can be applied on a routine basis in working practices. It was also noted that while there is relatively good data available for uranium mines, there is very limited data on radon levels and exposures in non-uranium mines. The potential doubling of calculated doses from radon progeny, due to the new information from the ICRP, adds to the importance of filling in this gap. Now in most of the Member States, there is also a gap of legislative revision based on the new ICRP recommendations on radiological protection against radon exposure. It is noted that the mines are first treated as existing exposure situations and they are also regulated as planned exposure situation based on the Member States' regulations.

TOPICAL SESSION 9:

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

Chairpersons: C. Cousins, United Kingdom and J. Vassileva, International Atomic Energy Agency

FOSTERING RADIATION SAFETY CULTURE — OCCUPATIONAL RADIATION PROTECTION IN HEALTHCARE

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Abstract

A selection of scenarios is described that illustrate desirable aspects of Radiation Safety (RS) culture in medicine. They concentrate on diagnostic radiology, but are, to a great extent, also applicable to nuclear medicine. The topics addressed include monitoring radiation workers and other staff; shielding (both structural and other forms); standards for equipment and their neglected importance; interventional radiology; and finally RS culture including its ethical framework. It is concluded that regular visits by the RPE are essential, and that the visits should include regular interactive communication with the radiation workers, particularly those at risk of exposure. Communication should be framed using the language of healthcare professionals. This has high recognition in hospital environments, where the language of radiation protection specialists is rarely used.

INTRODUCTION

The system for radiation protection has changed substantially during the last 10 years, particularly with the arrival of a new BSS from both the IAEA and EC, and a new medical foundation document from ICRP [1–3]. These were accompanied by unparalled levels of innovation in technology and clinical practice, which were, in turn, evident in the Call to Action that followed the 2012 Bonn Conference on Radiation Protection of the Patient.

In this short paper, we look at some of the cornerstones of the occupational radiation protection in healthcare. This includes personnel/area monitoring and Quality Assurance of equipment, but only the former will be discussed here. While distance is an effective way of dose reduction, we also must generally deploy shielding, both structural and as part of personal protective measures. One of the most dose intensive areas in imaging, Interventional Radiology, will be briefly addressed. Important to any culture is its ethical basis and the language it chooses to express itself.

MONITORING

A familiar manifestation of RS Culture is personnel monitoring. Effective dose to the whole body is routinely assessed and that to extremities, head, neck and eyes may be evaluated where significant risk arises. Protective measures include the old reliables: distance, lead aprons, thyroid collars and spectacles. Protective clothing can be uncomfortable, it degrades operator's performance, and may even cause injury (e.g.: chronic back pain). Improvements in good practice require that the Radiation Protection Expert (RPE) be regularly present to evaluate, encourage and be an advocate for more personalised approaches. Borowski advises strong ongoing presence of the RPE, particularly for those at risk [4].

Occupational exposure must be considered in the context of many serious risks that healthcare staff face and deal with on a daily basis. For example, blood and airborne pathogens including Hep C, HIV, Tuberculosis, and EBOLA are an integral part of the medical environment. Thus, the RPE in healthcare benefits from an access to highly skilled staff in appreciation of different types of risk. The RPE is expected, in practice, to ensure that visitors, patients and staff (not occupationally exposed) do not receive doses in excess of the public dose limit, or relevant dose constraints.

SHIELDING

Shielding is undervalued, if compared with the attention devoted, for example, to personnel monitoring. An important issue when undertaking shielding calculations is identifying the dose level acceptable outside the shielded area [6]. This question is largely neglected in the international community, and target values differing by over two orders of magnitude can be used by RPEs in different countries [6]. In Ireland, a dose constraint of 0.3 mSv/y is applied for areas to which non-occupationally exposed workers have access. This might include, for example, in the console area of CT or vascular X-ray suites. Published values used for workloads and occupancy of adjacent areas, in shielding calculations, do not travel well. It is more appropriate to determine the values used locally. Published values should only be used as a last resort [6].

It is essential that the RPE walks the area involved, understands the geometry of the facility and adjacent areas, including upper/lower floors, and the plans that staff have for the use of the facility and the adjacent areas. Special shielding problems arise when equipment mounted in trailers is deployed in a hospital or clinic.

EQUIPMENT STANDARDS AND INTERVENTION PROCEDURES

Good equipment compliant with international standards is an essential part of occupational protection [7]. Any doubt about this is removed by a consideration of the effectiveness of tube shielding, beam direction systems and exposure controls. These engineering solutions are the most important for staff protection, removing more than 99% of the radiation produced in the x-ray tube.

An important challenge for a RPE is to create a safe approach for health professionals who must be in the room during intervention procedures. This includes radiologists, cardiologists, gastroenterologists, orthopaedic surgeons, vascular surgeons and pain physicians, among other groups. The extent to which these groups are sufficiently knowledgeable to protect themselves is highly variable. If effective engineering solutions are available, they should be deployed, as they are often less dependent on the operator knowledge. In intervention suites well designed, ancillary shielding, particularly to the side of the table and suspended from the ceiling can greatly improve the radiation environment for operators without compromising dexterity and ergonomics. Regular presence of the RPE in the intervention suite is essential to ensure that the knowledge achieved in training programmes and well-judged shielding solutions, become part of routine practice.

Pain therapy using radiological guidance has spread rapidly and is now available throughout the world. In this and other applications, deploying mobile C-Arms, tube orientation and imaging detector position are not adequately used. In such cases, an optimum solution requires re-design of the configuration of the C-arm/patient couch arrangement. The level of the use now warrants innovative design to optimise staff and patient doses. The manufacturers and the Regulatory Authority should be engaged in these issues.

RADIATION SAFETY CULTURE RELATED ETHICS

The ICRP recommendations for a system of radiation protection consists of merging of scientific data with the values/judgments to allow that the policy objectives are achieved [1,8]. The value system used by ICRP is not explicitly stated, rather it is implied. It is clearly evident that the three principles *(justification, optimization* and *dose limitation*) have a low recognition in medicine. In the last two years a series of workshops sponsored by IRPA and ICRP has improved the ethical framework for RS in a small set of core values/principles derived from medical ethics. These are individual *dignity/autonomy; non-maleficence* and *beneficence*; and *justice* [8]. The principles/values are accepted in all cultures and appear well suited to the application in radiology. In addition, in radiology it is necessary to emphasise the *precautionary principle*, which requires that we act prudently when we have to act having incomplete knowledge. This is an approach that is a cornerstone for scientific advice in the environmental sciences. In addition, we need to address the issues of *openness, transparency and accountability* in communication with colleagues, public and the press [8]. The cultural armamentarium for RS includes the international and European BSSs, as well as working papers on the topic prepared by IRPA and SRP in the UK [1,3,8–10].

In addition, this paper identified that our culture should embrace three features: (i) closer contact with those to whom we provide services, (ii) regular visits, consultation, and walkabouts to the work places we serve; and (iii) a focus on safe FACILITATION of the hospital’s work, rather than on COMPLAINCE with regulation. The law may be good, but a good culture is better.

CONCLUSIONS

In conclusion, we must become much more conscious of the culture we work with, and bring it to a level of awareness that allows it to be critiqued, improved and expressed in a language that is known and accepted in medical institutions. The opaque language of radiation protection does not serve us well in this regard.

We have become too involved in delivering evidence of compliance to notice that many tasks need our input and support. Dose monitoring, equipment QA evaluations, acceptance testing and the associated reporting functions are important, but they are far from the whole issue. The full picture requires a much more concerted approach to shielding design and to ensuring that the equipment we have chosen is designed, built and installed according to valid international standards. It also requires that we become more aware of the potential of engineering solutions to deliver effective RP, as has been demonstrated in many aspects of equipment design, including the recent initiatives in paediatric CT design.

Finally, the Bonn Call to Action for patient protection gives an encouraging starting point for creating a similar initiative in the occupational area. Interestingly, at least nine of the ten major headings in the Bonn call are applicable to occupational RP [4].

ACKNOWLEDGEMENTS

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IMPROVING OPTIMIZATION IN OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

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Abstract

The largest contribution to medical occupational dose arises from intervention procedures due to the increasing number of procedures per year and the complexity of procedures. Protection and safety are optimized in accordance with the requirements of the BSS. Constraints should be established and used as part of optimization of protection and safety. Optimization needs to be considered in all stages of the life of equipment and installations, in relation to both exposures from normal and potential operations. This paper presents a survey of occupational exposure in diagnostic radiology, interventional radiology and cardiology, nuclear medicine, radiotherapy and dental radiology; and it discusses strategies and recommendations on improving optimization in occupational exposure.

INTRODUCTION

UNSCEAR reports that 3.6 billion diagnostic radiology examinations, 33 million nuclear medicine examinations or therapy procedures and 5.1 million radiotherapy procedures per year are performed worldwide on a high level of safety for patients and medical staff [1]. The largest contribution to medical occupational exposure arises from intervention procedures due to the increasing number of procedures per year and due to the complexity of procedures. In Europe, the number of coronary angiographies and percutaneous trans-luminal coronary angioplasty procedures increased by 264% and 416%, respectively, between 1992 and 2001 [2]

Occupational exposure is defined as all exposures of radiation workers incurred in the course of their work (with the exception of exposures excluded from the basic safety standard (BSS) and exposures from practices or sources exempted by the BSS). Detailed requirements for protection against occupational exposure are given in the BSS, while the recommendations on how to meet these requirements are given in the IAEA Safety Guidance on Occupational Radiation Protection, RS-G-1.1 and 1.3 [2,3].

Protection and safety are optimized in accordance with the requirements of the BSS and involve workers, through their representatives; the use of constraints is a part of optimization of protection and safety. Optimization needs to be considered at all stages of the equipment life, in relation to both exposures from normal and abnormal anticipated operations. Decision aiding techniques are useful tools to structure problems in order to compare the relative effectiveness of various protection options, to facilitate the integration of all relevant factors and to improve the coherence of decisions taken. Dose constraints can be used for optimizing protection in the planning stage for each radiation source. The BSS definition of dose constraint is: "For occupational exposures, dose constraint is a source-related value of individual dose used to limit the range of options considered in the process of optimization". Anticipated individual doses should be compared with the appropriate dose constraints and protective measures should be taken to keep doses below dose constraints.

The ERPAN survey shows that the majority of European countries have adopted the concept of dose constraints as an optimization tool for occupational exposure in the non-nuclear energy sector in their national legislation.

This paper presents a survey of occupational exposure in diagnostic radiology, interventional radiology and cardiology, nuclear medicine, radiotherapy and dental radiology; and discusses strategies and recommendations on improving optimization in occupational exposure.

OCCUPATIONAL EXPOSURE IN MEDICINE

A number of studies have reported the occupational doses to staff involved in diagnostic radiology, interventional radiology, international cardiology, nuclear medicine, radiotherapy and dental radiology (see Table I). The worldwide level of occupational exposures published by UNSCEAR for staff involved in all medical uses of radiation are presented in Fig. 1 and Fig. 2.

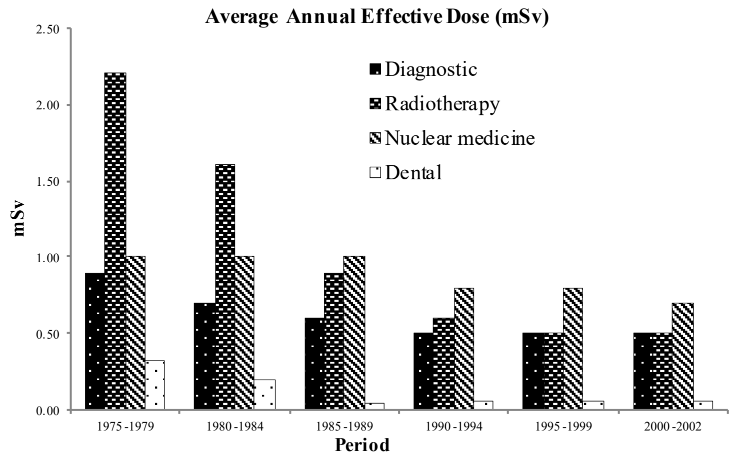

FIG. 1. Average annual effective dose for staff in diagnostic radiology, radiotherapy, nuclear medicine and dental radiology (1975–2002)

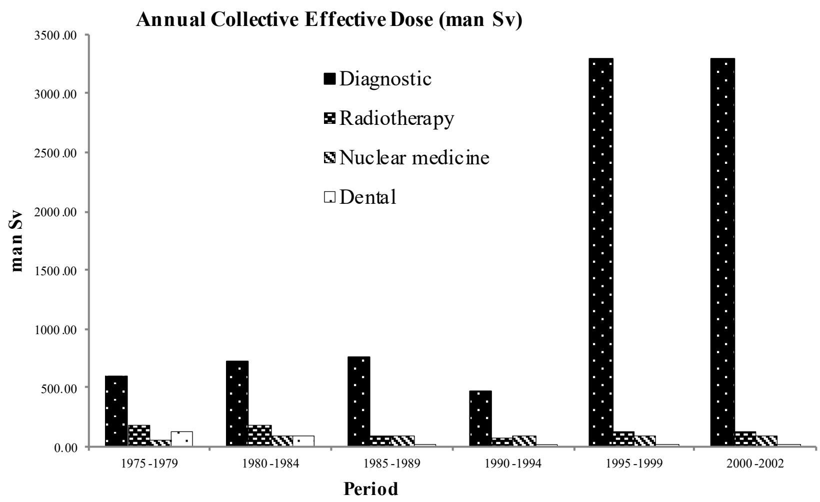

FIG. 2. Annual collective effective dose for staff in diagnostic radiology, radiotherapy, nuclear medicine and dental radiology (1975–2002)

TABLE I. AVERAGE ANNUAL EFFECTIVE DOSES TO STAFF IN DIAGNOSTIC RADIOLOGY, INTERVENTIONAL RADIOLOGY, INTERVENTIONAL CARDIOLOGY, NUCLEAR MEDICINE, RADIOTHERAPY AND DENTAL RADIOLOGY

Specialty	Category of staff	Average annual effective dose (range) (mSv)		
Diagnostic radiology	Radiologists		0.15[b]	
	Radiographers	0.06[b]		
	Nurses	0.07[b]		
Intervention radiology	Radiologists	0.35[b]	0.4[c]	2-4[d]
	Radiographers	0.25[c]		
	Nurses	0.31[c]		
Intervention cardiology	Cardiologists	0.20[b]	5[e]	0.536 (0.069 – 1.984)[f]
	Radiographers	0.154 (0.060 – 0.277)[f]		
	Nurses	0.154 (0.060 – 0.277)[f]		
Nuclear medicine	Physicians	0.4 (0.1-1.0)[g]		
	Technologists	0.71[b]	1.4 – 3.2[h]	1.8 (0.1-18.6)[g]
	Nurses	4.2 (0.4-13.4)[g]	0.70[b]	
Radiotherapy	Radiographers	0.5 - 2.5[i]		
	Nurses	1.0[i]		
Dental radiology	Radiographers	0.2[j]		

An initiative of the European Union, ORAMED (Optimization of Radiation Protection of Medical Staff) project was launched in 2008. The goals are focused on improving knowledge on extremity and eye lens exposures in medicine, combined with an optimization of the use of active personal dosimeters. A number of recent reports have indicated the prevalence of eye opacities in the staff exposed to radiation levels below the thresholds as established by the International Commission On Radiological Protection (ICRP). The values for detectable lens opacities are: 5 Sv for protracted and 0.5 - 2.0 Sv for brief exposure. The ICRP report (2007) concluded that "Because of the uncertainty concerning this risk, there should be particular emphasis on optimization in situations of exposure of the eyes".

IMPROVING OPTIMIZATION IN MEDICINE

— Diagnostic and interventional radiology

The increase of interventional and invasive fluoroscopy guided procedures has been substantial during the last ten years. Significant occupational exposure may arise during intervention procedures due to an inappropriate equipment and inadequate personnel protection. The main source of scattered radiation is the patient's body. Currently, radiologists, cardiologists and vascular surgeons performing high dose intervention procedures can be exposed to high doses. A busy intervention radiologist, who takes all appropriate radiation safety precautions will unlikely receive 10 mSv/year, while will likely receive 2–4 mSv/year.

Major findings from the ORAMED project, which should be considered for the optimization process, are as follow:

- Ceiling suspended shield can reduce the eye dose (2 to7 times)
- Alternatively, protective glasses with side shield should be used (90% dose reduction)
- The proper use of table shield can reduce the doses to the legs from 2 to 5 times.
- If bi-plane configuration is used, the proper use of lateral shield is very important because otherwise the eyes and hands are practically unshielded.
- Femoral access should be preferred. The doses, if the shields are properly used, are lower in the femoral access (2 to 7 times) compared to the radial access.
- Care should be taken for the table shield when assisting personnel stands close to the primary beam or when the operators need, for medical reasons, move around the table.

— Improving optimization in interventional cardiology

Recent studies reported that the most active and experienced intervention cardiologists (ICs) in high volume catheterization laboratories receive an annual effective dose around 5 mSv per year. Radiation dose to eye lens is a crucial issue for ICs. A retrospective assessment of the cumulative eye lens doses of ICs enrolled in the O'CLOC (Occupational Cataracts and Lens Opacities in interventional cardiology) revealed that for the 129 ICs who had worked for an average period of 22 years, received an estimated cumulative eye lens dose ranging from 25 mSv to more than 1600 mSv; (the mean ± SD (standard deviation) was 423 ± 359 mSv). After several years of practice, without eye protection, ICs may exceed the new ICRP lifetime eye dose threshold of 500 mSv and be at high risk of developing early radiation-induced cataracts.

The European Commission DIMOND III project proposed a preliminary occupational dose constraint by calculating cardiologists' annual effective dose and suggested this to be 0.6 mSv. It is difficult to predict operator's dose from patient's kerma area product mainly due to the different use of protective measures. However, it is important to note that the lower the radiation dose to the patient, the lower would be the scattered radiation received by the operator.

— Diagnostic and therapeutic nuclear medicine

In general, those handling unsealed radionuclides and preparing radiopharmaceuticals for diagnostic and therapeutic purposes receive very high dose. The application of beta emitters like Y-90 requires the use of appropriate beta shielding of the working place and use of rubber fingertip dosimeters on each finger to prevent over-exposures. Automatic dispensing tool should be used to reduce the finger dose.

Major findings from the ORAMED project that should be taken into account for the optimization can be summarized in the following:

- Doses are in general higher in non-dominant hand than in the dominant hand;
- The highest dose is often found to be received by the index tip of non-dominant hand;
- Dose distribution over the hand is inhomogeneous;
- The ratios between the maximum skin dose and the dose at the possible monitoring positions in the non-dominant hand are smaller than those in the dominant hand, except for the wrist;
- The smallest ratio between the dose at the maximum and the dose at a given position is found in the tip of the index finger of the non-dominant hand. However, this is not a practical monitoring position;
- The second smallest ratio is found for the index base of the non-dominant hand and thus the index base, on the inner side of hand, is the recommended monitoring position;
- The annual dose estimation exceeds 150 mSv (3/10 of the annual limit) for 51% of the workers;
- 20% of the workers exceed the annual dose limit of 500 mSv;
- A dose reduction between 1 and 3 orders of magnitude is achieved when using the appropriate shielding.

— Radiotherapy

Occupational overexposures in radiotherapy are rare. Non-optimised treatments due to over- or under-exposures often arise from systematic or technical errors and hence in many cases they are harmful to a group of patients. The conclusion from the majority of the analysed incidents and accidents is, that they could have been avoided by simulation and training of critical events. Several studies had reported that the average annual effective dose for radiotherapy workers ranged from 0.9 to 1.6 mSv.

In the 1980's, when radiotherapy sealed sources were implanted manually inside the body cavities, radiation oncologists and the nurses assisting them where receiving the highest radiation doses. Since then, the introduction of remote after-loading has significantly reduced the radiation doses to these workers. Still, brachytherapy requires special attention due to the storage of sealed sources, which emit radiation continuously; permanent implants and the need of source manipulation in permanent implant applications or, less frequently, applications involving manual source loading require attention.

— Dental radiology

Based on the UNSCEAR, the average annual effective dose for dental radiology is significantly lower, amounting 0.06 mSv over the period 1990 to 2002.

The ARPANSA Code of Practice (2005) for dental radiology states that:

"radiation protection for occupational exposure requires justification, optimisation and limitation to be applied to the practice which causes the exposure. It is recommended that dose constraints be used for certain work categories of the working environment. While dose limits mark the lower bound of unacceptability, dose constraints promote a level of dose control which should be achievable in a well-managed practice."

CONCLUSIONS

Highest occupational exposure has been recorded in intervention radiologists, intervention cardiologists and nuclear medicine staff members. It is expected that occupational exposure will increase as there is an increase in frequency and complexity of intervention procedures. Dose constraints should be established and used as part of the optimization of protection. Optimizing the patient dose will contribute to optimization of occupational exposure. Improved optimization will be achieved by focusing on education and training of the staff and more efficient regulatory framework along with a better equipment design. The staff of the regulatory authorities should implement necessary training, in order to ensure that optimization of protection and safety is adequately applied and enforced. Taking part in the IAEA clinical quality audit (QUADRILL, QUATRO and QUANUM) is another way how to reduce the doses to the operating staff.

Let us bear in mind that in the Joint IAEA and WHO Position Statement on the Bonn Call-for-Action (2012), occupational radiation protection was highlighted in Action 6, which focuses on an increase of availability of the improved global information related to medical exposures and occupational exposures in medicine by:

- Improving collection of dose data and trends on medical exposures globally, and especially in low- and middle-income countries;
- Fostering international co-operation, specifically improving data collection on occupational exposures in medicine globally, while also focusing on the corresponding radiation protection measures taken in practice;
- Making the data available as a tool for quality management and for the trend analysis, decision making and resource allocation.

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EDUCATION AND TRAINING OF HEALTH PROFESSIONALS IN OCCUPATIONAL RADIATION PROTECTION

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Abstract

Occupational exposure during fluoroscopy procedures and fluoroscopically-guided intervention procedures is relatively high. Intervention radiologists, cardiologists, vascular surgeons and their staff are at greater risk from exposure than other medical specialists. Education and training is a key prerequisite to ensure excellence in radiation safety. In the framework of the MEDRAPET project, six European societies, involved in radiation protection of patients and medical staff, have harmonized their methodologies in education and training in medical radiation protection and developed the European guidance on radiation protection education and training of medical professionals. The EUTEMPE-RX project aims at producing 12 modules to help Medical Physicists working in Diagnostic and Intervention Radiology to succeed in achieving Medical Physics Expert status. Occupational radiation protection topics are included in several modules of the EUTEMPE-RX. International organizations such as the IAEA, ICRP, WHO and the EC have taken important initiatives to provide training opportunities to healthcare personnel in occupational radiation protection.

INTRODUCTION

Fluoroscopy and fluoroscopically-guided procedures often deliver high radiation doses to both patients and staff due to prolonged fluoroscopy time and the increased number of cine acquisitions. Education and training in occupational radiation protection is of crucial importance for all medical professions working with ionizing radiation, especially for intervention radiologists, intervention cardiologists, electro physiologists, vascular surgeons, urologists, orthopaedic surgeons, gastroenterologists and gynaecologists. High level training courses are the key prerequisite to ensure excellence in radiation safety and in implementing strategies for dose optimization in medicine. One of the important activities of international organizations such as the International Atomic Energy Agency (IAEA), the International Commission on Radiological Protection (ICRP), the World Health Organization (WHO) and the European Commission (EC) is the education and training of health professionals in the occupational radiation protection.

MEDRAPET PROJECT

The EC launched the MEDRAPET (MEDical RAdiation Protection Education and Training) project in December 2010:

a) To assess the implementation of the Medical Exposure Directive provisions related to radiation protection education and training of medical professionals in the EU Member States;
b) To update the Radiation Protection 116 Guidelines.

The consortium responsible for the project was led by the European Society of Radiology (ESR) and included six European societies involved in radiation protection of patients and medical staff. As part of the MEDRAPET project, an EU-wide study was conducted in order to establish the status, legal and practical arrangements in the European member states regarding education and training of medical professionals in radiation protection. The results of this study were discussed during the workshop organized in Athens, Greece from 21 to 23 of April 2012. The conclusions of the workshop have lead into the elaboration of the European guidance document on radiation protection education and training of medical professionals (European Commission, Radiation Protection No 175). A pdf version of this document as well as more information about the MEDRAPET project can be found at the website.

EUTEMPE-RX PROJECT

The EUTEMPE-RX is an EC funded project which aims to provide training opportunities to medical physicists in diagnostic and intervention radiology to become Medical Physics Experts, i.e. to reach level 8 according to the European Qualification Framework (EQF). A network of excellent teaching centres in medical physics has been set up to develop a set of modules (Table 1). Occupational radiation protection topics are included in several modules, for example in modules 10, 11 and 12. The courses will achieve their learning objectives by combining online with face-to-face teaching.

ACTIVITIES OF INTERNATIONAL ORGANIZATIONS

It is well known that the IAEA has developed teaching material on radiation protection and provides online resources for all health professionals. IAEA organizes conferences, symposia, training courses and workshops. IAEA fellowships and scientific visits are very important training activities, since they provide practical on the job training. In 2014, the revised International Basic Safety Standards on Radiation Protection and Safety of Radiation Sources (BSS) were published, jointly sponsored by the European Commission, Food and Agriculture Organization of the United Nations, International Atomic Energy Agency (IAEA), International Labour Organization, OECD Nuclear Energy Agency, Pan American Health Organization, United Nations Environment Programme and World Health Organization. The new international BSS addresses patient exposure, occupational and public exposures and covers both normal circumstances as well as emergency situations of exposure. The revised BSS states that 'The government shall ensure that requirements are established for education, training, qualification and competence in protection and safety of all persons engaged in activities relevant to protection and safety'. Moreover, in the 'Responsibilities for protection and safety' section it is stated that 'the relevant principal parties and other parties having specified responsibilities in relation to protection and safety shall ensure that all personnel engaged in activities relevant to protection and safety have appropriate education, training and qualification so that they understand their responsibilities and can perform their duties competently, with appropriate judgement and in accordance with procedures'. For medical exposures, one of the requirements is that 'the regulatory body shall require that health professionals with responsibilities for medical exposure are specialized in the appropriate area and that they fulfil the requirements for education, training and competence in the relevant area.

TABLE 1. A SET OF MOODULES FOR TEACHING OF MEDICAL PHYSICS

Module	Topic	Organizer
1	Developments of the profession and the challenges of the MPE: Legal aspects, professional matters, communication and risk assessment, incidents and accidents, today and tomorrow. Raising the public profile of the profession. Basics of teaching RX users, interaction with the RPE	C. Caruana and E. Vano
2	Radiation biophysics and radiobiology: Integration of radiobiology and medical physics in radiation risk evaluation, research and management in D&IR	A. Ottolenghi, V. Smyth, K. Trott
3	Introduction to Monte Carlo simulation of photon and electron transport: application to x-ray imaging	J. Sempau
4	Fundamental physics of X-rays: energy, absorption and their phase for innovation purposes	M. Gambaccini, A. Taibi
5	Anthropomorphic phantoms	K. Bliznakova, I. Buliev, J. Vassileva, Z. Bliznakov
6	The development of advanced QA protocols for optimized use of radiological devices	H. Bosmans, N. Marshall, E. Vano
7	Optimization of X-ray imaging using standard and innovative techniques	K. Young, A. McKenzie
8	Role of Medical Physicists in CT imaging and patient dose optimization	F. Verdun, P. Monnin
9	Achieving quality in diagnostic and screening mammography	R. van Engen, W. Veldkamp
10	High dose X-ray procedures in interventional radiology and cardiology: establishment of a robust quality assurance programme for patient and staff	R. Padovani, A. Trianni, E. Vano
11	Radiation dose management of pregnant patients, pregnant staff and paediatric patients in diagnostic and interventional radiology	J. Damilakis
12	Personnel dosimetry – Clinical involvement: from device management to higher diagnostic effectiveness and dose optimization in diagnostic and interventional radiology	M. Borowski, M. Fiebich

IAEA held the “International Conference on Radiation Protection in Medicine: Setting the Scene for the Next Decade” in Bonn, Germany, in December 2012, with the specific purpose of identifying and addressing issues arising in radiation protection in medicine. The conference was co-sponsored by WHO. An important outcome of the conference was the identification of 10 essential actions for the strengthening of radiation protection in medicine over the next decade, among them to ‘strengthen radiation protection education and training of health professionals’.

WHO organizes sessions, workshops and other events on radiation protection and collaborates with other relevant partners to set up a global agenda on radiation protection topics. Moreover, WHO participates as an observer or contributor to radiation protection projects. WHO’s ionizing radiation unit has developed a wide range of information material and other publications.

The ICRP has published numerous publications on all aspects of radiological protection including occupational radiation protection. It is well known that the ICRP has developed the international system of radiological protection. The ICRP publication 120 on ‘radiological protection in cardiology’ includes protection of staff during fluoroscopically guided interventions and radiation protection education and training. The Commission has also provided recommendations for training in radiological protection in publication 113. Specific needs on training for those working with radiation outside imaging departments in terms of orientation of training and guidance on the curriculum are provided in publication 117.

The EC supports medical radiation protection through a variety of projects and publishes radiation protection guidelines and scientific findings in the ‘Radiation Protection’ series. The EC supports medical radiation protection through a variety of projects and publishes radiation protection guidelines and scientific findings in the ‘Radiation Protection’ series. In Europe, EURATOM (European Atomic Energy Community) regulates radiation protection. In 2014, the revised Basic Safety Standards (BSS) Directive was published that integrates five existing Euratom Directives. European member states need to incorporate the new safety standards into their national regulatory systems. Information and requirements for education and training of exposed health professionals in radiation protection are included in the new BSS.

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RADIATION PROTECTION OF THE STAFF IN INTERVENTIONAL PROCEDURES

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Abstract

Occupational doses to interventionalists are among of the highest observed in staff working in medical use of radiation. In addition, radiation doses to the lens of eye for intervention staff exposed to high workloads can readily exceed the 20 mSv dose limit for the lens of the eye, unless appropriate radiation protection measures are put in place. Radiation-induced eye lens opacities have been observed to reach up to 50% in some professional groups, such as intervention cardiologists as well as hair loss in unshielded portions of legs due to high doses. However, proper use of radiation protection devices, tools and techniques can maintain their annual effective doses below 10 mSv, typically within the range of 2 to 4 mSv, while the equivalent doses to eye lenses and extremities remains far below the limits.

INTRODUCTION

Intervention physicians, assisted by nurses and radiographers, in many medical applications, perform intervention procedures that are alternative to more complex open surgery. Not only patients, but also staff involved in the interventions, may receive substantial radiation exposure. Occupational doses to interventionalists are amongst the highest observed in the staff working in medical use of radiation [1]. Moreover, high radiation doses to the hands and legs have been reported to be accompanied by hair loss in unshielded portions of the legs [2]. Radiation-induced cataracts [3-6] and incidence of brain tumours among intervention cardiologists [7,8] have also emerged.

OCCUPATIONAL EXPOSURE

— Effective dose

Annual effective doses received by staff depend on the number of interventions, their medical complexity, the skill of the staff, fluoroscopic and cine times, use of protective devices, beam orientation, as well as the X-ray tube potential. While it is certainly possible for the interventionalists to properly use radiological protection devices, tools and techniques and to keep their annual effective doses below 10 mSv, (typically within a range of 2 to 4 mSv [9]), some surveys have revealed that individual occupational doses may be substantially higher [1].

— Extremities

The hands of the interventionalists are often placed near the irradiated place of the patient, where the scattered radiation originates. As the dose gradient around the patient is relatively high, there are variations in doses received by hands, depending on catheter entrance (femoral versus radial artery, percutaneous access for biliary ducts, transjugular access) and on whether the irradiated volume of the patient is the head, the chest, the abdomen or the legs. Femlee et al. conducted measurements of the radiation dose to hand using TLD ring badges for individual intervention radiology cases. Results from over 30 interventions on the upper abdomen (including trans-hepatic cholangiograms and biliary and nephrostomy procedures) indicated an average hand dose of 1.5 mGy per intervention, while the largest dose measured in one intervention was 5.5 mGy [10]. Hands should not usually be exposed by the primary beam. Scattered radiation, transmitted by the patient body in an x-ray under-couch geometry, delivers dose rates ranging typically from 2 to 5 $\mu Gy\ s^{-1}$. Direct exposure to the incident primary beam from an over-couch x-ray tube could be even 50-100 times greater. Configurations with the x-ray tube above the patient are therefore not recommended for the x-ray guided interventions. While the recommended x-ray tube in under-couch geometry saves exposure to the upper body and to the hands, if no table shielding curtains are used, the radiation scattered down from the patient and directed toward the legs of the intervention staff can deliver doses to the legs that can be higher than those to the hands [11].

— Equivalent dose to the eye lens and the reported eye lens injuries

The dose to the eye lenses has received increased attention as evidence has become available that cataract development may have a much lower threshold than it was believed. New ICRP recommendations have reduced the annual limit to the eye lens from 150 mSv to 20 mSv. Studies have shown that annual doses to the eye lenses of some intervention staff may be at the level of 50 mSv to 100 mSv [3,12-15]. Therefore, radiation doses to the eye lenses of the intervention staff with high workloads can readily exceed the 20 mSv dose limit, unless appropriate radiation protection, measures are put in place. This has been illustrated by cases of eye lens opacities reported in 1998, where the reason was a non-optimized radiation protection in the intervention radiology laboratory [5] [Vano et al. 1998]. Later, in 2004, Z. Haskal presented at the RSNA the results of the pilot study of x-ray-associated lens changes in 59 practicing intervention radiologists; 37% of those screened had detectable posterior lens changes consistent with the radiation exposure [16,17]. This observation has been further confirmed by more recent studies coordinated by the IAEA (RELID programme: Retrospective Evaluation of Lens Injuries and Dose) [3,4,6,18,19]. RELID studies have shown that 50% of intervention cardiologists and 41% of nurses and technicians, who voluntarily underwent ophthalmological controls at their scientific congresses, have posterior sub-capsular lens changes, characteristic for ionizing radiation exposure, compared with <10% similar lens changes in the control groups [19]. Moreover, a recent RELID study revealed a significant loss of contrast sensitivity in this staff, compared to the standardized normal vision data [19].

EXPOSURE MONITORING

— Effective dose monitoring

Effective dose is usually estimated from the readings of personal dosimeters calibrated in terms of personal dose equivalent, Hp(10), which provides a moderate overestimation of the effective dose. The staff inside the intervention room wears protective aprons that protect organs and tissues of the trunk, and collar shields that protect the thyroid. For this reason, if a single dosimeter is used above the collar, its reading overestimates effective dose by a factor of more than 10, while a dosimeter placed under the apron takes no account of doses to the head, neck, and the lungs and other organs in the thorax that are exposed via the arm holes [20,21], therefore its readings underestimate effective doses. The assessment of effective dose can be somewhat improved by using two dosimeters, one over and one under the apron, and combining their readings by means of a simple algorithm. The algorithm takes the form:

$$E = \alpha H_{tu} + \beta H_{na}$$

where H_{tu} (reading of the dosimeter on the trunk under the apron) and H_{na} (reading of the dosimeter at the neck above the collar shielding). Different empirical pairs of α and β values have been proposed and adjusted to various radiation geometries. Within the European CONRAD, the study 11 pairs of α and β values have been compared with measurements and Monte Carlo simulations and concluded that none of them is an optimum for all possible geometries and therefore, compromises have to be made when making a choice [22].

Although, in principle, the two-dosimeter approach gives a better accuracy, it has also important drawbacks, namely:

1) The lack of international consensus on the α and β values renders effective dose comparisons meaningless;
2) The cost of two dosimeters is higher;
3) The reliability of clinicians wearing two dosimeters correctly and consistently is questionable.

If the dosimeter positions were inadvertently reversed, the result of applying the formula would lead to a substantial overestimation of the effective dose. Martin and Magee [23] have proposed that a reasonable indication of the effective dose (E) for staff involved in radiology procedures, who are wearing a protective apron, can be obtained from the simple relationship:

$$E = 0.1 \times H_{na}$$

where H_{na} is the personal dose equivalent Hp(10) measured at the neck above the collar shielding. According to this proposal, a monthly value of H_{na} of the order 20 mSv (Emontly ≈ 2mSv) would be of the order of the effective dose limit. In this case a more accurate dose assessment using two-dosimeters approach would be warranted, together with the investigation of the working practice, aimed at finding the reason for higher doses.

— Monitoring of eye lens exposure

Behrens et al. investigated the adequacy of the operational quantities at the depths, 0.07, 3 and 10 mm for the assessment of eye lens equivalent dose from x-ray fields [24] (Behrens 2012) and concluded that both quantities Hp(0.07) and Hp(3) are adequate when the dosimeters are calibrated on a slab phantom simulating backscattered radiation. Similar results were reported by the ORAMED Project [25] (Vanhavere et al.).

A practical approach consists of using the collar dosimeter as an indicator of the eye lens dose without lead glasses and applying a correction factor when lead glasses are used [23]. When the monthly collar dosimeter reading approaches 1 mSv and no protective eye lead glasses are worn, a more accurate determination of doses to the eye-lenses may be warranted. This can be achieved by a dosimeter worn close to the most exposed eye. An investigation of the working practice is recommended in these cases, in order to find the reason of the high doses.

— Extremity exposure monitoring

Proper dosimetry to evaluate doses to the hands and fingers is not easy in clinical practice. The most common method consists of a wrist dosimeter, but due to the high gradient of the radiation field near the patient and the possibility that part of the hands are exposed by the direct beam, doses measured by the wrist dosimeters could be much lower than the finger doses. For the majority of procedures, the outer side of the hand is closer to the primary beam, thus receiving higher dose, so dosimeters should be worn either on the little finger or at the outer side of the wrist closest to the beam [25,26].

RADIATION PROTECTION MEASURES OF THE INTERVENTION STAFF

Most of the dose reduction methods to protect the patient result, in a similar proportion, also in reduction of the dose to the staff., These methods include keeping fluoroscopy time and cine runs, maintaining the distance between the patient and the image system and the use of higher dose rate modes to the minimum necessary for the intervention. Additionally, protection of staff only is given by the shielding devices, as well as stepping back from the patient for cine runs.

— Ceiling suspended screens

The most important protection of the head is the proper use of shielding devices [5, 27]. Ceiling-suspended lead acrylic shields should be a mandatory requirement for the intervention installations. If deployed effectively, they can reduce doses to the head and neck by factors of 2-10. However, actual dose reduction depends on the regular use by interventionalists and how effectively they are positioned.

— Aprons

Intervention staff working inside a fluoroscopy room wears aprons made of rubber or vinyl impregnated with lead. They shield the trunk against scattered radiation, but leave the head and neck, arms, hands and legs unprotected. The apron contains the equivalent of 0.25 mm or 0.35 mm of lead and some designs have an overlap to provide protection of 0.5 mm lead equivalence at the front. Transmission is typically between 0.5% and 5% in the range of 70 kV to 100 kV [28]. Several different designs of lead apron are available, some of which aim to reduce the ergonomic hazards in order to minimise risks of back injury. Two piece aprons consisting of a waist coat and skirt allow some of the weight to be supported at the hips to reduce strain on the back [8].

— Protective goggles

The majority of protective goggles are equivalent to 0.75 mm or 0.5 mm of lead and many have protection in side-shields of 0.5 mm or 0.3 mm lead equivalence and dose reduction factor of 5 to 10 have been reported from experimental measurements from x-rays incident from the front in the same horizontal plane as the eyes [13,29-32]. However, the actual dose reduction in practice needs to take account of X-ray beams incident from the side and below the level of the head, similar to those encountered in clinical practice. A close fit to the facial contours is required, as the glasses must also provide protection against radiation scattered from the face of the staff, i.e., from below and from the side.

— Protection of the hands

Ceiling suspended screens provide good protection for the head and upper body, but the hands are generally positioned below the screen and so receive less protection. Lead/rubber drapes attached to the bottom edge of the screen can be effective in protecting the hands for some procedures [25]. Protective drapes and pads can also offer good protection for the hands and have been shown to achieve a 29-fold reduction in the dose to the hands [32].

Thin protective gloves are available, but reports of the protection offered vary (15-60%). Users may be given a false sense of safety about the level of protection afforded and the staff may take less care, believing that dose reduction is more significant. If a hand protected by a glove strays into the X-ray field, it may partially shadow the sensor of the automatic exposure control and the dose rate will be increased to compensate for the attenuation, thereby increasing patient dose without benefit to the staff [34]. New shielding materials (e.g. Bismuth) have been proposed also as hand cream for hand protection [35].

— The legs

Lead/rubber curtains attached to the side of the couch usually have a lead equivalence of 0.5 mm and provide the operator with the best protection [36,37] [Whitby and Martin 2003, Shortt et al 2010]. Table shields can reduce doses to the legs by factors of 10 to 20 if correctly positioned throughout a procedure [38] [Martin 2009], but factors between 2 and 7 are typical in practice [25] [Vanhavere et al 2012]. Such shields should be required for all intervention cardiology and radiology facilities.

A screen that is integral to the table has the advantage of being as close as possible to the source and is always in place so that no conscious decision is needed to use it. For the majority of procedures, where the cardiologist or radiologist stands at the side of the table, such as angiography, biliary, stents, embolization and angioplasty, the screen integral to the table provides the better option. However, for taller operators the couch may on occasions be raised too high to fully protect the feet.

HEALTH SURVEILLANCE

Health surveillance has to be based on the general principles of occupational health and designed to assess the initial fitness and continuing fitness of workers for their intended tasks. Some workers may have exceeded the new dose limit to the eye lenses. An eye examination need not be undertaken prior to starting work, except for the purposes of determining the fitness for the intended task. Workers, who have not received doses to the lens of the eye of more than 20 mSv in a year on average over their working lives, need not be subject to any additional medical examination beyond what is required by the above general principles of occupational health. Workers who have already received accumulated doses to the lens of the eye of more 0.5 Gy or who, even if now subject to the new dose limit, may, after a few more years, accumulate doses in excess of this level may need to be subject to regular visual tests. [39].

RADIATION PROTECTION PROGRAMME AND QUALITY ASSURANCE

The programme has to include the assignment of responsibility for radiation protection and for training, procedures for the selection of the appropriate radiological equipment, protective devices and detection and dosimetry instruments, availability of personal protective devices, and their features should be regularly controlled; results from personnel and workplace monitoring should be recorded, as well as the necessary corrective measures must be taken in response to unusual results. Procedures should include investigation, reporting and recording results, as well as corrective actions in case of incidents or accident. A quality management system should be established at institutional level and completed with regular and independent audits, internal and external.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 9

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INTRODUCTION

A total of 42 papers, from 34 different countries, were submitted for the session on occupational radiation protection in medicine. This represents the largest number of papers submitted for a session within the conference. The papers covered a wide range of topics including:

- Eye Doses
- Interventional radiologists/cardiologists
- Dose surveys
- Radiotherapy
- Pregnant workers
- Nurses, maintenance workers, TSOs
- Shielding reviews
- Dental radiology

CONTRIBUTED PAPERS

A number of papers considered the recent change to the dose limit for the lens of the eye and the impact that this will have on workers in the medical sector. O'Connor et al provide a review of a study carried out between 2011 and 2014 involving eye doses to 30 staff at two Irish hospitals from more than 1900 X-ray and PET procedures. The authors note that where right and left eyes were monitored in interventional radiology and cardiology the dose to the left eye was always higher than the dose to the right eye, and that an interventional radiologist/cardiologist/gastroenterologist may exceed the new EU threshold for Category A workers of 15 mSv to the lens of the eye if adequate eye protection is not worn or if the X-ray tube is overcouch. The paper also highlights that some staff in the study work in more than one hospital and recommend that there is a need for greater communication and sharing of personal dosimetry data among employers.

Nikodemová et al report on an eight month pilot study involving three interventional cardiologists who performed 242 interventional procedures. The study showed that the new eye dose limit can be exceeded while whole body doses recorded for the same period can be less than 5 mSv. The study also found a broad range of measured values as a function of equipment used, dose area product values, fluoroscopic time, available protection tools and also the BMI of patients. These differences were also observed when only one type of interventional procedure was undertaken which indicates the significant role that training and education of the medical staff has on dose reduction and optimization.

An assessment of the effectiveness of wearing protective eyewear by interventional radiologists, as well as the accuracy of the measurement of Hp(3), was carried out by Sarti et al. The measurements carried out by the authors show that the average attenuation factor of the eyewear anti-X is equal to ~ 4 (range 3.3–5.2). An evaluation of using Hp(0.07) recorded on dosimeters placed at chest level to provide a conservative estimation of the dose to the lens of the eye for historical situations is also presented.

Tuohy et al present the findings of a study of eye dosimetry for seven interventional and cardiology staff over a six week period. The authors note that while a number of recent studies have suggested a reasonably strong relationship between received eye dose and corresponding DAP data for interventional procedures, the data in their study does not support those findings, However the authors do suggest that there may be factors in their study that may explain this. The data from the study shows that eye doses for interventional radiologists and cardiologists will likely approach the EU Category A worker classification level of 15 mSv/yr and accordingly eye dose monitoring will be introduced for all these workers. The study also showed that nurses who work in close proximity to the patient during the interventional procedures receive significant doses to their eyes and will also require monitoring and that this nursing role should be rotated among a number of staff.

Sánchez et al describe in their paper the results of the use of a solid state dosimeter for real time personal dosimetry for more than 600 fluoroscopic guided procedures. The dosimeter was worn over the apron to estimate eye lens doses. The results obtained confirm that in the case of interventional cardiology, interventional neuroradiology and interventional radiology, the average dose per procedure are consistent with those published by ORAMED. The authors estimate that where ceiling suspended screens or lead glasses are not used, the dose limit for the lens of the eye would be exceeded after only 400 – 500 interventional procedures per year. The results also demonstrated that the use of ceiling suspended screens reduce the scattered dose to the interventionist by a factor of 13–24.

An assessment of the exposure of staff during Hysterosalpingogram (HSG) procedures in nine medical clinics in Nigeria is detailed in the paper by Adeyemo & Audu. The authors note that the ineffectiveness of the TLD monitoring service within Nigeria in recent times has increased the fear among medical practitioners in relation to their participation during HSG procedures, which require close proximity to the scattered beam during exposures. Based upon the measurements obtained, the authors conclude that all doses arising from these procedures are below the acceptable dose limits for occupational workers. The authors suggest that the doses received can be reduced by cautioning staff in terms of patient procedure number, the introduction of shielding enhancements and increasing in the number of staff involved. In addition, they recommend that the monitoring of staff in the one centre that use a fluoroscopy unit for the procedure is essential.

Two papers were submitted which looked at occupational doses in dental radiology. Bahreyni et al report on the monitoring of organ dose of four radiographers over a month. The study considered doses received from intraoral, periapical, digital panoramic and CBCT examinations. Overall, the authors conclude that although digital panoramic and CBCT deliver the highest organ doses to the radiographers, these are substantially less than the annual limits set by ICRP (estimated to be less than 2 mSv/yr in all cases).

In the second paper on dental radiology, Bylyku & Qafmolla report that the mean annual effective dose of occupational staff in dental clinics in Albania has been evaluated to be about 0.8–1.0 mSv for the last five successive years (2009–2013). The authors concluded that the individual doses, and therefore individual risks, from dental radiology are low in comparison with those from other forms of diagnostic radiology; however, they note that there is scope for marked improvement in the diagnostic standards of dental radiology in Albania.

The protection of pregnant workers in radiotherapy departments is considered in two separate papers. Cruz et al describe how a limit of 0.35 mSv per month, as measured at the deep dose dosimeter of the mother, was established to ensure the protection of the unborn child.

Cordero-Ramirez in his paper outlines the steps that are taken in a radiotherapy department to ensure the on-going protection of the unborn child once a pregnant worker declares her pregnancy.

The reduction of occupational doses in PET facilities is covered in a number of papers. Paolino et al describe how doses in a PET production facility were reduced following a modification to the production laboratory layout and location of the laminar flow. Despite a 243.5% increase in production of FDG, doses to workers only increased by 20.3 % during this time. Similarly, hand doses to workers involved in the production of FDG only increased by 35.8% during this increased production period.

Hudzietzová et al report on the results of hand doses to workers involved in the preparation and administration of F-18 labelled radiopharmaceuticals at three different nuclear medicine departments in the Czech Republic. The authors note that there are quite large discrepancies in local doses at various workplaces, with the differences mainly attributed to factors such as the individual approach of the workers performing specific operations, the use of slightly different techniques, the technological equipment and conditions at each department, and last but not least, the use of shielding and protective tools. The use of semi-automatic dispensing feeders proved to result in substantial reduction of the exposure of workers and their extended applications are recommended. The authors conclude that, based upon the result obtained, compliance with relevant regulatory requirements depends largely on the skills and experience of workers and their professional competence which has to be refreshed from time to time and updated in specialized training courses.

Hernández et al describe the safety systems, training programmes and operational procedures that are commonly used at PET radiopharmaceutical production facilities in Cuba to ensure the protection of workers. In particular they stress that staff training cannot be underestimated considering the risks involved and the complexity of the technology used.

Abdalla et al report on an analysis of how modifying techniques for the preparation and administration of FDG can reduce staff doses. The authors describe how the introduction of an automatic injector reduced staff doses by a factor of four, while training successfully resulted in a dose reduction by a factor of ten.

In their paper Salminen et al describe a study where workers in a major PET centre in Finland, involved in the synthesis of F-18, C-11 and Ga-68, will be monitored for eye lens, finger and whole body doses. Although only limited data were available at the time of the writing of the paper, the authors noted that in the first four weeks' measurements, exposure differences related to different tasks and differences in the individual exposure level among workers on the same tasks were observed. In addition, even though similar protective eyewear was used, the authors observed substantially different attenuation with similar protective glasses during F-18 and C-11 synthesis (12% vs. 21%), noting that this would need confirmation from additional measurements. The results of additional measurements will be included in the poster at the conference.

Abughaith et al describe how changes introduced at the Kuwait Cancer Control Centre resulted in decreases in occupational doses. In particular, the introduction of automatic injectors for the administration of FDG to patients resulted in a 40% reduction in whole body effective dose for PET Physicians. In addition, the introduction of improved/increased shielding in the FDG production unit resulted in a reduction of whole body doses for the cyclotron staff, from an average of 13 mSv in 2011 to 7 mSv and 6 mSv in 2012 and 2013 respectively.

A new method for the experimental evaluation of operations when handling FDG is described in a paper by Fülöp et al. The method is based upon the unfolding of integral distribution of skin doses measured in 10 different locations on the hands and allows for the identification of particular operations/procedures that lead to significant contributions to the local irradiation of skin on hands during the manipulation of radiopharmaceuticals. The results obtained have determined that the right hand is mainly irradiated by FDG applications with the shielded syringe held among the fingers and the thumb, whereas for the left hand, irradiation is mainly due to the holding of the infusion tube with FDG. This has made it possible to design more targeted radiation protection measures for the protection of nuclear medicine workers.

Sarti et al present a review of doses to workers preparing and administering F-18, Tc-99m and Y-90. For work involving the handling of F-18 and Tc-99m, the authors note that absorbed dose to the hands of the workers who prepare the radiopharmaceutical, doing the same tasks, vary between 1.5 mSv and 24.2 mSv, while the doses to the operators who administer the drug vary between 1.22 mSv and 31 mSv. The highest values correspond to staff still in training or to situations where complications occur. In terms of the dose to the lens of the eye, these were found to be negligible in the radiopharmaceutical phase and less that 0.1 mSv in the administration phase. For the administration of Y-90, it was noted that the measured doses to the lens of the eye correlate with the doses measure at the fingers, and while they are not negligible, they do not exceed the new limits.

The evaluation of radiation occupational exposure for workers in a Brazilian radiopharmaceutical facility between 2011 and 2013 is described in a paper by Carneiro et al. Between 205 and 221 workers were monitored each year, though the authors note that all workers at the facility were monitored regardless of their work activities. Overall, 30% of the workers monitored received doses exceeding 2.4 mSv/yr, contributing 60% to the collective dose. The highest annual effective doses were received by three different workers, namely 15.02 mSv, 19.08 and 21.12 mSv in the years 2011, 2012 and 2013 respectively. Optimisation improvements introduced at the facility included operational measures such as modernization of the production lines and hot cells and improvement in the packaging system. The authors also recommend that continuous training of workers in safety principles and good practices should be reinforced, independent of the amount of handled activity.

Shubina & Kornosheva describe the results of monitoring occupational doses in interventional radiology departments in Estonia during the period 2009–2013. Between 2009 and 2012 there was relatively little variation in average annual doses for interventional radiology, however in 2013 the average effective doses for interventional physicians and nurses increased by a factor of two. The authors suggest that this increase could have been caused by several things, including for example the involvement of specialists with insufficient training in the interventional diagnostic and treatment procedures. The authors recommend that, in light of the increases observed in 2013, radiation protection measures must be reviewed regularly and upgraded accordingly to take account of technology development.

A review of the annual doses received by 30 workers, over a 30 month period, at a state hospital in Bolivia is presented by Huanca Sardinas et al. The authors note that the highest doses received during the study period were to two interventional cardiologists. These two workers received 43.7 and 23.1 mSv, whereas the highest doses recorded by technicians who are also present during the procedures were 11.2 and 29.4 mSv. In their discussion the authors note that refresher training providing for interventional cardiologists does not include any radiological protection content, and suggest that this omission is due to either the lack of knowledge or an understanding of level of importance that should be afforded to this topic.

Begum et al describe a study of occupational doses of workers in 49 medical facilities in Bangladesh between 2010 and 2013. Most occupationally exposed workers received very low doses with only a small number receiving high doses. Among the exposed workers, it was observed that the highest average dose was received by the workers in interventional cardiology department. Even though seven radiation workers (two physicians and five non-physicians) exceeded the average annual dose limit (20 mSv/yr), with the highest recorded dose being 49.37 mSv, no worker exceeded the maximum annual dose limit.

The use of disposable, sterile and lead free protection drape (RadPad) to reduce occupational exposure in interventional radiology is considered in a paper by Khamizah et al. The authors present the results of attenuation measurements made on two different types of RadPad protective drapes, demonstrating that their use can significantly reduce the scattered radiation dose to staff during a prolonged fluoroscopy-guided procedure. However, the authors note that one of the drapes may increase the level of backscattered radiation dose to the patient and that further work is required to investigate this.

Alves et al looked at the doses received by the dominant hand of an interventional radiologist using a needle holder during 34 biopsy procedures where CTF guidance was necessary. The results obtained suggest a significant dose reduction on the exposure to the hand of the radiologist almost by a factor of 10, highlighting the importance of using needle holders as a protective tool for optimization of radiological protection in CTF procedures. The findings also suggest that when a needle holder is used the similarity of the dose values on all fingers, irrespective of the position (tip or base) minimizes the uncertainty on the selection of the dosimeter position. In the absence of a needle holder tool the results suggest that the dosimeter should be worn on the tip of the index, middle or ring fingers.

Bentayeb et al report on the results of a preliminary dosimetry study of occupational radiology in Moroccan hospitals. Based upon a study of four doctors in a cardiology department over three months, it can be clearly observed that the nature of the procedures being carried out, together with the experience of the doctor, strongly influence the doses received.

A comparison between doses received by workers in private hospitals versus those in public hospitals in Zimbabwe is the topic of a paper from Ncube et al. Data were analysed from two public and two private hospitals for the period January 2012 and May 2014. The results showed that initially the doses received by workers in public hospitals were higher than those from private hospitals by a factor of two, but these gradually decreased and by 2014 the doses for each sector were comparable. The authors cite a number of reasons for this successful reduction in dose, including training programmes run by the regulatory body, additional resources being provided by the State to public hospitals and the adoption of good safety culture, working practices and engineering standards by workers.

Tarabiah et al describe an analysis of occupational doses of 755 workers in eight hospitals in Qatar between 2009 and 2013. Ninety nine per cent of all annual doses were below 5 mSv, with the highest annual doses recorded during the study period of 5.79 mSv (Cath-lab technologist) and 5.46 mSv (interventional cardiologist). The authors comment that the personnel monitoring programmes make the workers more aware of their doses and lead to improvements in their radiation protection practices.

Castilho et al report on a study of occupational doses from 20 endovascular procedures for hepatic chemoembolization using active dosimeters. The measurements obtained from the study demonstrate that doses received in the ankle region are about 10 times higher than in other regions suggesting the importance of installing table-mounted lead drapes for the physicians. As expected, the effective doses received by nursing staff were lower than the physician's doses; however, the measurements obtained support the justification of nurses wearing front and back shield aprons.

In their paper, Vasquez Ibanex & Huanca Sardines describe a retrospective analysis of 60 TLD readings between 2009 and 2013 for workers in the radiopharmacy and radioimmunoassay areas of the nuclear medicine department at the Universidad Mayor Real & Pontificia de San Francisco Xavier of Chuquisaca in Bolivia. The authors conclude that radiation protection standards are met at the facility, noting that there was a variation in the results from both areas, reflecting the use of different diagnostic radioisotopes.

The validation of the double dosimetry method, used for the assessment of the effective dose of interventional cardiologists, is the subject of a paper by Chumak et al. The authors describe in-situ phantom measurements, taken within the operating room for 14 and 12 working days in the course of regular interventional procedures, involving 2010 and 2146 single radiation situations for the two study periods. For input into the computer simulations, 12 values of photon energy, nine c-arm angulations and four different fields of view were considered. In general, experimental in situ validation of the NRCRM double dosimetry algorithm under real life exposure conditions demonstrate excellent accuracy and robustness of dose estimates provided by the algorithm. However, the authors note that the straightforward application of other popular algorithms gives results which significantly overestimate actual effective dose. This difference is caused by the approach used for development of the NRCRM algorithm.

Kishta et al describe exposure measures and personal dosimetry results for 100 interventional procedures carried out at the Mother Teresa Hospital, Tirana, Albania. The authors calculate that where lead aprons and thyroid collars are not used, the dose limit of 20 mSv per year will be exceeded after 320 procedures. However, by using aprons and collars the number of procedures that can be undertaken, before the annual dose limit is exceeded, increases to more than 3000. Scatter dose measurements show that a sanitary or other assistant, standing at a distance of 2 m or more during fluoroscopic procedures can participate in one procedure a week without exceeding the 1 mSv/yr dose limit for non-professional exposed workers and members of the public.

Several papers deal with the issue of shielding in medical environments. Lavin et al report on shielding deficiencies encountered in lead operator screens and a wall adjacent to a wall stand bucky in a general X-ray room. The investigation into how these issues arose identified the causes as both a lack of experience and expertise by the manufacturer of the operator screen and a failure to consult with a Qualified Expert during an upgrade to a room. The authors recommend that a Qualified Expert should be consulted in advance of the acquisition of protective equipment or making changes to a facility where ionising radiation is used. Furthermore, they recommend that all protective equipment and barriers are assessed before any ionising X-ray equipment is put into clinical use.

Bradley et al describe a series of operational improvements that were made to an iodine-131 ablation facility to enhance occupational radiation protection following an incident in 2005 where a maintenance department worker was exposed to a low (<10 μSv) but unnecessary dose. The response to the incident resulted in the hospital reviewing all procedures relating to the use of the facility, including how a 1000 litre holding tank was used, the designation of areas, the dispersal of airborne iodine-131, and the handling of bed linen/towels, general domestic and clinical waste.

Kiragga et al report on a survey of radiation doses received by workers in four departments in Mulago Hospital in Uganda. Measurements of scattered radiation were made within four rooms and personal dosimetry was carried out for two workers in each department. On average, across the locations surveyed, an occupational exposed radiation worker in Mulago hospital received 4.31 mSv/yr.

Gϋndoğdu & Ovacilli describe the requirements for personal protective equipment to protect against ionising radiation in the health sector. They make a number of recommendations including that equipment used for radiation protection should be selected on the basis of compliance with the PPE Directive rather than the Medical Devices Directive, that hospitals should take account of the manufacturer specified life time of products that incorporate a layer of lead, that manufacturers should certify their products according to the PPE Directive and that, similar to the requirement for workers to use personal dosimeters, the wearing of lead aprons should be made compulsory.

The paper submitted by Samba et al describes how the National Radiation Protection Agency (NRPA) of Cameroon commenced a national personal dosimetry service in June 2011. Prior to this it had been estimated that only 12% of over 500 occupational exposed workers were being monitored by external dosimetry services. By 2014 the number of monitored workers had increased to 250 (30% of total no. of exposed workers) with a reduction in the average whole body dose from 1 mSv/yr in 2011 to 0.3 mSv in 2014. The paper also describes the regulatory controls and requirements that have been introduced by the NRPA that are improving the radiation protection culture and attitudes of workers in Cameroon.

Two papers were received that consider radiation protection in radiotherapy. Paz Garcia Beltran & Godínez Sánchez describe how SEVRRA (risk evaluation software tool), developed by the Mexican Regulatory Body (CNSNS) in cooperation with FORO, was used to carry out a risk assessment for radiation workers arising from mechanical failures, miscalibrations, human errors in a radiotherapy department. Risks were computed as a function of the frequency of the initiator event, their consequence magnitude and the robustness of safety barriers to the accident initiator events. Accident initiator events are described for linear accelerators, cobalt-60 teletherapy treatment units, HDR and LDR brachytherapy units as well as safety barriers for the protection of radiation workers for facilities with linear accelerators. This analysis will allow CNSNS to recommend governmental plans that provide for good regulations and laws in radiation safety matters, the promotion of the setting up of new installations, accurate decision making and improving the cost-profit of inspections and licensing activities.

The challenges in occupational radiation protection at an advanced radiotherapy facility in Pakistan are discussed by Warsi et al. With the advancement in technologies such as stereotactic radio-surgery and high energy radiotherapy, new challenges such as shielding calculations for complex techniques such as IMRT and Cyberknife, availability of neutron dosimetry and emergency preparedness are arising. Further challenges include the unavailability of Technical Support Organisations (TSO), the lack of a formally qualified workforce and the non-existence of formal professional bodies for radiation protection. The paper outlines these challenges in detail and the remedial actions taken by the Pakistan Atomic Energy Commission to address them. It is interesting to note that the authors state that the most important factor in addressing these challenges is the frequent training and retraining of all stakeholders working in the area of radiotherapy.

In a paper by Mustafa M Elamin & Rafet AH Abushammala, the strategy adopted by Mafraw Hospital, Abu Dhabi, UAE, in determining whether the hospital should establish its own internal dosimetry service is described in detail. Details of the SWOT analysis undertaken by the project team are provided and the various steps taken during this project are described.

The topic of radioactive waste generated in a nuclear medicine department is addressed in a paper by Guimarães et al. An analysis of the personal dosimetry records for 12 workers over two years was carried out with respect to the amount of waste generated. Not surprisingly the magnitude of the doses received by the workers each month was directly related to the amount of procedures performed at the hospital and the associated waste generated. The median whole body dose for the period of the study was 0.6 mSv/month and 1.6 mSv/month for wrist dosimeters, with the highest doses recorded as 1.4 mSv/month and 8.5 mSv/month for whole body and wrist dosimeters respectively.

The use of Technical Support Organisations (TSO) to provide necessary radiation protection services in Kenya is described by Rugut & Wambani. The Radiation Protection Board of Kenya (RPB) has established a number of memoranda of understanding with TSOs to complement the Government's efforts in promoting competence and involve a wide range of health and safety professionals in order to identify inadequacies and oversights in facilities using radiation. These TSOs provide quality assurance, quality control, dosimetry and radio analytical services which have allowed the RPB to identify challenges and gaps under such heading as equipment and facilities, protocols and personnel, which need to be addressed in order to ensure safe practice.

CONCLUSIONS

Many of the papers submitted report on the results of occupational dose monitoring programmes, with evidence of average doses reducing in many cases being reported. However, high doses are still being received and, in the case of interventional workers, whole body doses of up to 50 mSv/yr have been reported at this conference. This serves as an important reminder that further work is still necessary to ensure that workers are encouraged and supported to work in a safe manner so that occupational doses are kept as low as reasonably achievable. Part of the solution has to include continuous education and training programmes, and this is a common theme that runs through many of the papers. In particular, "training" is mentioned in 25 papers and "education" in 12 papers. The papers are clear that training should not just be provided to operators, such as interventional cardiologist and radiologists, but also to other professions such as nurses, TSOs and maintenance workers.

In light of the recent revisions by ICRP to the lens of the eye dose limits, many papers report on dose surveys that looked at typical eye doses received in practice. What is clear from the surveys reported is that this is an important issue for workers involved in activities such as interventional cardiology and radiology, but it doesn't appear to be an issue for PET or nuclear medicine procedures. Many papers report on the effectiveness of personal protective equipment such as eyeglasses and ceiling suspended shields, however these can only be effective if routinely used by workers.

Another issue that was raised is the fact that many interventional workers practice at a number of different hospitals, incurring doses at each centre which may be recorded on different dosimeters. In order to be able to properly monitor these workers there is clearly a need for greater communication and sharing of personal dosimetry data among employers.

Several authors report on initiatives where operational doses to workers have been reduced through the successful introduction of simple shielding devices such as syringe shields, lead glasses, automatic injectors and lead free protection sheets or following a reassessment of the on-site physical shielding barriers. While some of these solutions are quite easy to introduce, it is important that they be used properly and backed up by appropriate education and training programmes.

Finally, the role of the regulatory body in reducing operational doses has been identified as playing a significant contribution in several of the papers. A number of authors describe the important role that regulatory bodies have made through for example, the provision of national dosimetry services, the running of training courses and the implementation of routine regulatory controls to improve the safety culture among employers and workers and ultimately reduce occupational doses.

CHAIRS' SUMMARY OF TOPICAL SESSION 9

In this session, there was a topic keynote lecture, three topical presentations and a rapporteur summary of over 40 contributed papers.

Prof J. Malone, Ireland presented on 'Fostering radiation safety culture: occupational radiation protection in health care'. Topics covered included monitoring of staff, shielding, issues in intervention radiology and occupational radiation protection culture, including ethical issues. There is a need to customize individual protection, which is often seen as uncomfortable, distractive and inhibits performance. Shielding lacks global standardization and is generally poor in mobile x-ray units. In intervention radiology, appropriate room design is crucial, and this requires liaison with engineers and staff. Ceiling suspended and table side lead shields should be essentials. Ethical issues are very important and as well as the basic principles, additional themes of being prudential, precautionary, openness and transparency have to be considered. Good cultural practices need to be encouraged extending beyond individuals to the stakeholders, including professionals, unions, patients and the wider community. In daily practices, radiation protection culture needs to be examined, reflected on and become pervasive. The new Basic Safety Standards should help to facilitate radiation protection culture, but it should be remembered that 'law is good, but a culture is better'. Three S's can be used to summarize the main factors: Standards are required for equipment; Shielding should be designed for purpose and Skills and knowledge are needed in practice.

Dr S. Saiffudin, Malaysia, presented (on behalf of Prof K. Ng, who unfortunately was not able to attend the meeting) on 'Improving optimization in occupational radiation protection in medicine'. The majority of European countries have adopted dose constraints as an optimization tool for occupational exposure in the non-nuclear energy sector into their national legislation. The ORAMED project (commenced in 2008), focused on improving knowledge on exposures in medicine and on optimization of the use of personal dosimeters. The highest doses are received by staff working in intervention radiology, intervention cardiology and nuclear medicine, although there have been reductions in doses achieved over the last 40 years. However, occupational doses may increase with the increasing frequency and complexity of intervention procedures. It should be remembered that the main source of scattered radiation is the patient's body and by reducing patient dose, scatter is reduced and so is the dose to the operator. Optimization can be improved by placing greater emphasis on the education and training of staff and by ensuring that there is appropriate equipment design and better regulatory framework.

Dr. I. Damilakis, Greece presented on 'Education and training of health professionals in occupational radiation protection'. This emphasized the important role of a medical physics expert in the training of other healthcare professionals with regard to radiation protection. The MEDRAPET (medical radiation education and training) project, which commenced in 2010, highlighted the lack of harmonization of radiation protection training and education. Several organizations including the European Commission, IAEA, ICRP and EFOMP are active in the field of education and training in occupational radiation protection and these were briefly outlined. The EUTEMPE-RX consortium was also described. This will run until 2016 and will develop and evaluate new training schemes for medical physics experts working in diagnostic and intervention radiology.

Dr. P. Ortiz Lopez, Spain presented on 'Radiation Protection of the staff in interventional procedures. The occupational exposure of interventionalists is among the highest occupational exposures of all medical use of ionizing radiation. Many medical specialists are now involved in fluoroscopically guided procedures, often with no training in radiation protection. Using appropriate techniques and protection devices, interventionalists may keep their annual effective doses in the range of 2-4mSv. Cataracts and opacities in the lens of the eye have been observed in up to 50% of intervention radiologists and cardiologists. The problems of wearing personal dosimeters in different sites on a person were highlighted, particularly as the reliability of staff wearing two dosimeters correctly and consistently is often questionable. The importance of wearing personal protection devices and using both ceiling and table mounted shielding was emphasized. Employing different techniques to reduce dose during procedures was described.

Dr. S. Fennell, Ireland was the rapporteur for the session and summarized the contributed papers. There were 42 papers submitted from 34 countries on a wide range of topics. Several common themes emerged. There was an evidence that occupational doses are generally decreasing, although some high doses do still occur. Education and training were included in many papers, with the recognition that radiation protection should be included in refresher training. Eye doses are of concern for interventionalists and while it is accepted that protection devices do work, they do have to be used. The important role of regulatory bodies in occupational radiation protection was highlighted. It was also recognized that as advances are made both with equipment and techniques, these will lead to new challenges in occupational radiation protection.

The discussion included the perception that many individuals in healthcare are still unaware of many of the issues of occupational radiation protection, using other imaging modalities e.g. ultrasound and magnetic resonance imaging, which are useful for selected diagnoses and for therapeutic intervention, where treatment may knowingly result in high doses to both the patient and, the staff.

The main conclusions from all of these presentations was that all actions to protect patients and reduce their dose will, in addition, protect the staff and that both patient and occupational radiation protection should always be considered together.

TOPICAL SESSION 10:

OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR/ FUEL CYCLE FACILITIES

Chairpersons: F. Vermeersch, Belgium and B. Breznik, Slovenia

OCCUPATIONAL RADIOLOGICAL PROTECTION PRINCIPLES AND CRITERIA FOR DESIGNING NEW NUCLEAR POWER PLANTS

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CRPPH Expert Group on Occupational Exposure (EGOE), OECD/NEA, France

Abstract

In 2006, the CRPPH (Committee on Radiation Protection and Public Health) of the Nuclear Energy Agency (NEA) agreed to create an ad-hoc Expert Group on Occupational Exposure (EGOE) to broadly scope out policy and regulatory issues that could be usefully addressed by the CRPPH in occupational radiation protection (ORP) within the nuclear power industry. The EGOE identified the ORP as a key topic to be considered in early stage (design), for optimisation purposes. The Group carried out the study based on experience and lessons learned from the existing fleet of reactors, on the ISOE (International System on Occupational Exposure) databases and members [1], and on international references (a list is available in the OECD report). Some decision making criteria are also presented. The report was published in 2010 and is available through the NEA homepage [2]. Considering that new nuclear power plants could be planned and erected in a near future, and that most of them would be of the 3rd generation and might be designed for operating as long as 80 years, substantial consequences for ORP can be expected, for instance regarding the number of generations of workers involved, the knowledge management and the evolution of RP requirements during such a long time. On behalf of the EGOE, the presentation will go through its report, enhancing on identified key topics.

More information can be found at the link: https://www.oecd.org/publications/occupational-radiological-protection-principles-and-criteria-for-designing-new-nuclear-power-plants-9789264098046-en.htm

PRACTICAL CHALLENGES IN ONGOING NPP DECOMMISSIONING

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Abstract

Decommissioning of nuclear power plants is a part of the life cycle of each nuclear power plant. In general, an effective occupational radiation protection program ensures that workers are adequately protected against ionizing radiation and doses are not only beyond dose limits but become optimized taking into account the ALARA principle. Past and recent decommissioning projects show that radiation protection during decommissioning follows the same concepts as during operation, but that some aspects will gain more importance due to the different nature of decommissioning when compared to the operation. Within this contribution a brief status quo on the occupational radiation exposure during decommissioning of nuclear power plants is given, some factors for a successful optimization in occupational radiation protection are addressed and still existing challenges are discussed.

INTRODUCTION

At a first glance, occupational radiation protection (ORP) during decommissioning might be regarded to be the same as during outage of a nuclear power plant (NPP) in operation. Similar to outage at a NPP, ORP during decommissioning has to consider that activities are performed in high dose rates and at work places with contaminations or risk of contamination with radioactive material. Accordingly, procedures, protective systems and equipment from operation deem appropriate to ensure ORP also during decommissioning. Nevertheless, a closer look at the situation reveals that differences exist or aspects known from operation gain more importance, e.g.:

- Continuous change of the facility due to the decontamination and dismantling activities – systems may not be available anymore, the radioactive inventory changes, work instructions requiring adaptations, radiation sources may appear and disappear again;
- Increased number of (long-lasting) work activities with interdependencies – high need for coordination of all activities to avoid radiological consequences;
- Access to workplaces not accessed during operation and outage – a need to handle unknown radiological situations;
- Occurrence of deviations between plans and real situation at the workplace, e.g. due to differences between blueprints and reality, unexpected radioactive material – risk of spontaneous changes of plans without analysis of (safety and radiological) consequences and adaptation of plans and measures;
- High volume of material flow, including flow of radioactive material and activated and contaminated components, through the nuclear facility – storage areas, capacities for handling and processing of radioactive material and to control material entering / leaving the radiation controlled area gain much higher importance;

- Depending on the progress of dismantling replacement of technical barriers e.g. by administrative barriers – personnel protective equipment becomes more important and human error might have higher impact on safety and radiation protection; and
- Long-lasting increased number of personnel during all the year in the radiation controlled area – management of the personnel and migration of personnel and its equipment is more extensive.

Experience from past and recent decommissioning projects shows that ORP can be ensured and optimization of the radiation exposure to workers during decommissioning is possible. But still some aspects of further improvement exist.

STATUS QUO ON THE EXPOSURE RELATED TO NUCLEAR POWER PLANT DECOMMISSIONING

The Information System on Occupational Exposure (ISOE) [1] jointly co-sponsored by the OECD Nuclear Energy Agency (OECD/NEA) and the International Atomic Energy Agency (IAEA) is a worldwide network of operators of NPPs and national regulatory bodies to collect information and to exchange experiences on the occupational radiation exposure of workers in NPPs. While having in the past a strong focus on aspects of NPP in operation, ISOE improved (and still is improving) its decommissioning related capabilities to collect more detailed information and data on the occupational exposure of workers in NPPs (e.g. ISOE database on occupational radiation exposure) and to further foster the exchange of ORP experiences (e.g. regular ISOE ALARA Symposia).

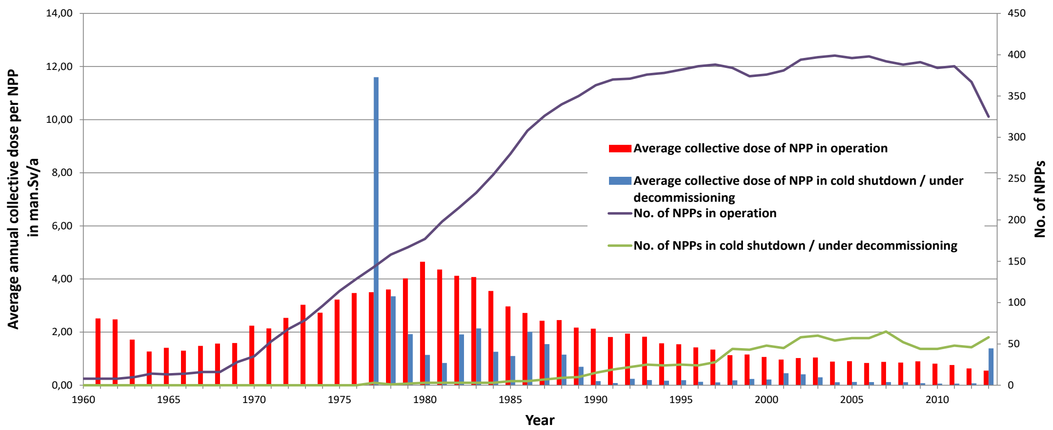

FIG. 1. Average annual collective dose per NPP worldwide, based on data from ISOE [1]

Fig. 1 presents the average annual collective dose for most of the NPPs worldwide in operation and in cold shut down or some stage of decommissioning. The figure shows that for the average data of the annual collective dose for nuclear power plants in cold shut down / under decommissioning is since 1990 lower than for nuclear power plants in operation. It is important to notice that the average collective dose for cold shut down / decommissioning depends on the annual contributions from a varying number of NPPs and from their individual decommissioning schedule and related annual work performed (this, in principle, is true for NPPs in operation due to their annually changing outage programs, but as typically a core set of similar activities can be expected for every one NPP or sister group of a NPP and due to the high number of contribution NPPs the variations as less distinct).

Fig. 2 presents the annual collective dose for an exemplary boiling water reactor (BWR) and an exemplary pressurized water reactor (PWR) for their period of operation and their subsequent, still ongoing period of cold shutdown / decommissioning. Similar to those of Fig. 1, the data show that the annual collective dose is significantly lower during cold shutdown / during decommissioning compared to the period of operation. The differences are inter alia a consequence from the absence of spent nuclear fuel during decommissioning in both examples and reduced dose rate fields and level of system contaminations due to conducted full system decontaminations.

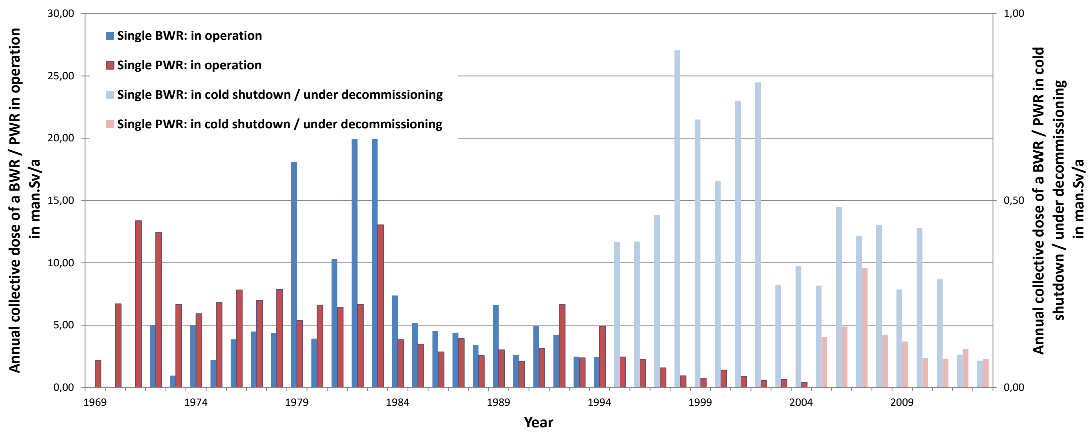

FIG. 2. Annual collective dose for a single boiling water reactor (BWR) and a single pressurized water reactor (PWR) during their full life cycle, based on data from ISOE [1]

SELECTED FACTORS FOR A SUCCESSFUL OPTIMIZATION IN OCCUPATIONAL RADIATION PROTECTION

Several factors already known from operation of a NPP contribute to the overall success of the optimization in ORP. Three factors are discussed below in some details.

— Overall planning process and work control

As a common practice from operation, the planning of ORP measures needs to be part of the overall planning process for any decommissioning / dismantling activity (but also for any work activity to maintain, inspect, repair or replace systems still needed). The overall planning process typically determines the individual work steps and their sequence, the techniques to be used; the protective measures and the material (waste) expected to be generated and to be further processed. Within the overall planning, the dismantling activities are assessed with respect to at least fire protection, occupational radiation protection and industrial worker protection and to any potential impact on safety relevant systems.
The radiation protection experts of the NPP should be involved in the overall planning process as early as possible to ensure that relevant input information on the radiological situation will be considered in time, missing information is retrieved immediately or as part of a dedicated program, and that the radiological situation is assessed in parallel to the technical planning and that specific protective measure, training needs, advice on ORP improvements (e.g. conduct of decontamination measures, use of remote tools) are identified and integrated in the planning. The extent to which the ORP-related planning is needed should depend on the radiological

criteria (e.g. dose rate at the workplace, planned maximum individual dose, planned collective dose) and which should be defined within the system of ORP related regulations.

It's a good practice that the dismantling activities are based on written work permits covering also ORP measures and that during the dismantling activity the work conduct is controlled also with respect to ORP. A high intensity of the ORP related work control is especially important when the planning indicated high dose rates / high levels of contamination at the workplace or in those cases, in which the radiological situation is, not known well. To improve internal ORP related experience feedback, a comparison of planned and real doses (maximum individual effective dose, collective dose) should be performed and deviations in both directions should be analysed.

— Sound and robust system of ORP regulations

To handle the continuously changing situation in a NPP under decommissioning, a system of ORP regulations should be available which comprises at least a two tier design of documents. The upper tier ought to be high level defining the overall ORP principles (e.g. definitions, dose rate / contamination level zoning concept, dose constraints and action levels to trigger protective measures, concept on characterization of the NPP including the concept on how to define the radionuclide composition relevant for ORP and material / waste characterization), general procedures (esp. on the ORP planning process, on the concept of work permit and on work control and monitoring processes) and the ORP organization including ORP responsibilities. The lower tier ought to provide a set of instructions on the daily work activities and on specific technical aspects (e.g. on how to monitor work places, dose rates and contamination levels, how to take and analyse samples, how to handle and manage generated material and radioactive waste, including the control of the build-up of radiation sources due to dismantling of components, on RP measures specific to individual dismantling technique as e.g. thermal cutting) which need to consider the continuous changes and an increasing likelihood of contaminations e.g. when defining frequencies of monitoring.

The system of ORP regulations needs to be consistent, duplications between the elements of the two tiers should be limited to the extent possible (without jeopardizing an easy reading) to avoid inconsistencies and to improve the process of maintaining the system of ORP regulations. The systems should be part of the overall decommissioning manual (i.e. the former operation manual, adapted to the particularities of decommissioning) and needs accordingly to be subject to an integrated quality management (including a transparent tracking of documents).

— Radiation source control

The most effective way to keep workers' doses ALARA is to keep dose rates and contamination levels as low as reasonably achievable. Accordingly, radiation source control requires inter alia that:

Dose rates and contaminations are monitored carefully. Special emphasis should to be given to those areas which are frequently accessed (e.g. stairways, gangways, storage rooms for tools etc.); especially with respect to contaminations special emphasis should be given to entrances /exits areas to/at workplaces in which dismantling activities are performed which may result in airborne contaminations (independent from mandatory measure to avoid airborne contamination spreading). The monitoring provides input to start immediate actions if corresponding action levels are exceeded and to the overall planning process.

Any contribution to workers' radiation exposure from dismantled material should be as low as reasonably achievable. Accordingly, already during the planning of the dismantling the transfer, processing and (temporary) storage of dismantled activated or contaminated component should be assessed; special emphasis should be given to phases during which the dismantled component is at the workplace or close to frequently accessed areas.

CHALLENGES AND CONCLUSIONS

Experience shows that ORP during decommissioning can be based on the ORP during operation of a NPP, but adaptations are needed. Past and ongoing projects on the decommissioning of NPPs show that the radiation exposure of workers is less compared to the exposure during operation on a high level and that the optimization in ORP is possible. However, still some challenges (or potential for further improvement) exist to ensure a successful optimization in ORP:

Although experiences cannot be transferred one by one from one project to another, experience from different decommissioning projects may help to improve own measures. Already today, initiatives at IAEA (e.g. IAEA International Decommissioning Network IDN) or at OECD/NEA (e.g. Working Group on Radiation Protection Aspects of Decommissioning Activities in Nuclear Power Plants of the ISOE, Working Party on Decommissioning and Dismantling WPDD) provide the frame for such exchange. But, due to commercial restrictions, such exchange might be less detailed than desirable – thus new ways are needed to solve this situation and to balance the individual interest.

Transferring decommissioning related knowledge, especially on concepts and procedures as laid down in the decommissioning manual, including the system of ORP regulations, and keeping a level of high but appropriate awareness of the individual workers on radiation risks associated with the remaining radioactive inventory and the dismantling activities are especially in case of replacement of workers (e.g. due to retirement, job rotation, involvement of outside workers) of high importance to keep radiation exposure limited. Although an issue since several years there is still a need to further exchange practical hands-on experiences and approaches.

REFERENCES

[1] Information System on Occupational Exposure (ISOE)
Homepage of ISOE: http://www.isoe-network.net/.

RADIOLOGICAL PROTECTION AT A REPROCESSING PLANT

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Abstract

The Sellafield site in Cumbria comprises a large number of buildings including reprocessing and waste treatment facilities within a relatively small area. The facilities have been constructed over a period of 60 years with experience from earlier plants used to influence the design of later plants. The differing designs and conditions prevalent in the facilities mean that, in order to successfully deliver radiological protection, a flexible approach using different approaches has been needed. High hazard reduction has required a longer term view of ALARA balancing short term risks of intervention with longer term reductions in risk.

INTRODUCTION

The Sellafield Site in Cumbria is approximately 2 km long by 1 km wide and contains approximately 200 nuclear facilities ranging from the very large to relatively small. The facilities are in close proximity and have many interactions/effects on nearby facilities. Nuclear activities started on the site in 1947 in order to produce defence materials for the UK weapons programme. Expertise on the site was then used in the early development of civil nuclear power leading to the Magnox Reactor and AGR programmes. Learning from the operation of early facilities led to new facility designs from the 1980s onwards, with commercial reprocessing starting in the 1990s. The current focus of the site is on decommissioning which will require the construction of new facilities as well as the clean up and demolition of old facilities.

APPROACH TO RADIOLOGICAL PROTECTION

The wide range of plant ages, designs and radiological hazards (levels and isotopic fingerprints) mean that it is difficult to set prescriptive arrangements for radiological protection that would be effective across the whole site. Instead a range of techniques have been developed which are applied singly or in combination, depending upon the situation (e.g. a new standalone facility would be approached differently from an addition or modification to an existing active plant). Delivering effective and flexible radiological protection in this way places a high reliance on the professional judgement and experience of radiation protection advisers and other specialists.

In the early years of the site dose rates and doses were higher than on modern plants and the highest individual doses were approaching the then limit of 50 mSv (5R) per year. The new plant designs of the 1980s included improved shielding and containment plus true cascade ventilation systems. This resulted in gradually reducing dose uptakes as the workforce were increasingly working on newer facilities. An emphasis on dose reduction in the 1990s pushed doses lower still, until it became rare for anyone to exceed 50% of the 20 mSv dose limit and detectable internal doses were virtually eliminated.

More recently there has been a realisation that the radiological hazard over the lifetime of facilities is also important and that it is appropriate in some cases to accept a short term higher risk (including higher doses) in order to remove or greatly reduce a risk in future years. It is therefore likely that in the near term the doses to some key decommissioning groups will increase above current levels though still remaining within acceptable dose limits.

TECHNIQUES USED FOR RADIOLOGICAL PROTECTION

— Dose targets and review levels

Sellafield Ltd has a workforce of approximately 10,000 employees plus around 3,000 contractors. Between these groups, the Sellafield site has an annual collective dose in the region of 6.5 man Sieverts Man.Sv. Whilst a proportion of this collective dose is due to large numbers of people receiving small doses, it remains essential to closely monitor and control the doses. Due to the different situations, different control arrangements are used for employees and contractors.

Sellafield Ltd employees are organised in similar dose groups and are usually fixed in one plant or group of plants. Doses for each group are predicted for the year and a "Local ALARP Review Level" (LARL) set to flag up if their doses are exceeding the prediction and enable an investigation to be carried out. The LARL is not a limit and individuals or groups can exceed it if justified. At 10 mSv, a more in depth review is held to ensure it is ALARA to go higher.

Contractors are more mobile between plants and between contracting companies. In order to have some consistency between contractors, and ensure that doses are planned over a whole year, a "Stargate" system is used where contractor manage their own doses from day-to-day, but there are thresholds at 4 mSv/a, 6 mSv/a, 8 mSv/a and 10 mSv/a where contractors have to justify moving into the next dose band.

Doses to employees and contractors remain very similar in terms of average annual doses and maximum individual doses. No one at Sellafield Ltd has received an annual dose of more than 10 mSv over 10 years, however this is expected to change in the future to enable some high hazard reduction work to take place.

— Balance of risk / perception of risk

A key aspect of radiological protection is informing and training the workforce so that they can understand radiological risks and put them in context with other risks they encounter. This helps to ensure they are making logical decisions in their work and minimise their overall risk rather than focusing on a small or trivial radiological risk whilst increasing their risk from another hazard. It is not easy or quick to do this, but it can pay large dividends when successful. To assist in this, all Sellafield Ltd radiation protection advisers and safety advisers are required to achieve a significant level of knowledge in both radiological and conventional safety, so that they are well placed to balance the risks. Workforce training includes sessions to prompt discussion/thinking on how harm from radiation exposure might compare to conventional injuries such as a broken leg. The reprocessing plant environment contains significant conventional hazards (e.g. chemicals, working at height, asbestos and large scale transport) which are more likely to significantly harm workers than the radiological hazards.

— Optioneering

Optioneering is a form of multi-attribute analysis and is used to prompt brainstorming of options and as a decision making tool between options. Impartially, following the process is important in achieving the right outcome, but not as important as selecting a representative mix of the relevant disciplines to take part. Firstly, possible options are identified and then criteria against which they can be judged are listed such as external dose, maintainability, timescale. The options are then scored against the criteria and ranked according to score. It is essential to test the sensitivity of the decision to minor changes in score and continue to use professional judgement where scores are close. It is often worthwhile assessing a "do nothing" option in order to balance the short term risk of intervening with the long term risk of waiting.

— Simulations

Sellafield Ltd is making increasing use of simulations and mock ups both for basic training, where radiation worker training is carried out in a simulated plant and for specific tasks/projects where techniques can be developed, optimised and practiced in a low hazard environment. This is also a method whereby operators are given a significant input to fine tune arrangements and become proficient at tasks which may be one offs. Simulators have also been used to train personnel not normally doing hands on work to do simple high dose rate tasks under the supervision of plant operators.

— Pre and post work reviews

Sellafield Ltd uses pre and post work ALARP checklists to guide radiation protection advisers to ensure that all aspects are considered and recorded before work starts and to capture any learning from the task so that it can be used in future work.

Pre assessments include such matters as whether the task is necessary, engineering options (e.g. shielding), past experience on similar tasks, removal of the radiation source, decontamination, containment, distance, waste generation, occupancy and having low dose rate refuges.

Post assessments consider more of the detailed practical aspects and how they went e.g. " were the required tools and equipment available on time?" or "were all individuals involved aware of the radiological risks and controls before work commenced?"

The predicted doses are also linked to the plant modification process with tasks ranked as low, medium or high and the amount of justification / reviews related to the significance of the task.

— Design standards

Sellafield has a series of radiological protection design standards covering topics from changerooms design to activity in air coverage. The current target for new plant designs is that average annual doses are less than 2 mSv with no individual exceeding 5 mSv/a. These are over and above the current external guidance but, in aiming for these levels, designers are achieving significantly better design than expected. The design standards help to deliver a consistent approach but these are guidance only, plant radiation protection advisers are required to interpret them, e.g. for modifications to an existing plant where a mismatch in standards may not be desirable.

— Culture

Whilst designers can make significant contributions by reducing or engineering out radiological hazards, ultimately the safety of a nuclear plant depends on the culture of the people working on it.

WORKPLACE EXAMPLES OF THE APPLICATION OF ALARA

— Retrieval of Alpha air filters from a legacy facility

A project was established to look at retrieval of plutonium contaminated filters stored in an old unventilated building heat sealed in pvc in approximately 200 stillages. The filters had been there for some time dating back to the 1960s and the pvc was beginning to degrade. Dose rates from the filters ranged from background up to a few mSv/h and there was a concern regarding the potential for a contaminated wound if these old filters were handled.

An optioneering exercise was carried out with options including waiting for better remote handling technology, construction of a ventilated overbuilding and overboxing whole stillages. The option selected was to construct a small temporary containment within the building and repackage the filters into the same stainless steel containers as are used for modern filters.

This presented a number of challenges in terms of dose control and manual handling so a full mock up was constructed with different equipment provided for the stores operators to test and use to develop the best techniques.

The filters are now all in modern stainless steel containers in a modern store. By making the containers the same as modern containers, it has made the final conditioning and disposal simpler and not left avoidable hazards for future workers to address. The solution from the operators has safely reduced the hazard at a fraction of the cost of an engineered project and probably five years earlier.

— Retrieval and conditioning of waste from silos.

One of the legacies from the early years of the operation of the Sellafield site is that some wastes were stored in silos leaving the solution of how to retrieve and condition the waste to be addressed in the future. The area around the silos contains other facilities leaving little room to construct facilities for retrievals. The silos are inerted and dose rates within them are substantial as the material consists of items such as fuel cladding. Options were limited as the dose rates preclude any significant manual operations. A new plant has been re-designed according to modern plant design standards and is now partially constructed to safely retrieve the waste. The available space for the new plant was a significant constraint and part of the plant has had to incorporate an existing active process pipeline whilst controlling doses to workers during construction and operation of the new facility.

— Glovebox housekeeping

One of the older operating plants on the Sellafield site incorporates a lot of alpha gloveboxes and the age of the plant means that dose rates from the ingrowth of Am-241 have a significant effect on worker doses, which were typically up to 10 mSv per year. Discussion of options for cleaning the gloveboxes had taken place over many years, but had always been discounted due to the magnitude of the predicted doses to carry out the cleaning combined with uncertainty from operators and managers as to whether it could be sustained. It was not considered to be ALARA to carry out this cleaning.

Following a change of managers it was decided to clean the gloveboxes. The workforce was involved in planning the work and dose reduction but it remained doubtful over whether this target would be achieved or sustained. The cleaning was completed with significantly less dose than historic assessments had predicted, partially due to the work being completed faster and partially by targeting higher dose rate areas first.

After the clean up, the first time any material was released within the glovebox, the workforce was convinced that everything would go back to how it used to be. However, the manager shut the plant down until it was cleaned and established a culture of not accepting any degraded condition and the workforce now take pride in the cleanliness of their gloveboxes. This is a clear example of leadership setting the right culture and it reduced doses to the workforce by 80%.

— Radiological Rollback

As a result of Sellafield's history where facilities have grown and developed over time, there are some very large controlled areas and the culture when designing a new plant was to replicate what was currently working on operating plants where individual cells were linked by large controlled areas with changerooms at the boundary. With the introduction of Nuclear Management Partners as the Parent Body Organisation for Sellafield Ltd, this was challenged and a number of changes have been made.

New plants are being designed such that cell subchangerooms are being designed and maintained so that a controlled area is not needed beyond them. Where possible existing plants are being "rolled back", so that contamination is retained within smaller and smaller areas. One example of this is in the area where fuel flasks are imported into the Magnox reprocessing plant. The flask design incorporates a drip tray which is removed prior to docking the flask onto a gamma gate. The plant was modified enabling the drip tray to be removed right next to the gate resulting in a much smaller contamination area. As well as being safer, the cost of the changes would be paid for by a reduction in the amount of PPE needed.

A further example was within THORP (Thermal Oxide Reprocessing Plant) which is a modern plant where there has been little contamination in the controlled areas outside of cells. This is a very large area and in order to roll it back it required a lot of work monitoring the whole plant, fixing or removing contamination spots and labelling inaccessible areas which couldn't be monitored. The most time consuming work was discussing the arrangements and consulting the workforce who were initially concerned about the safety of the proposal. Following the implementation, the area has been successfully maintained as a supervised area, personnel have the culture that they do not accept any contamination and anything detectable is immediately investigated and removed. Operators have also made significant contributions redesigning equipment and procedures to prevent contamination. Rollback has acted as a kick start to further improvements in contamination control.

SUMMARY

Judgment of what is ALARA is subjective and coloured by individual's perception of risk which depends upon their experience/knowledge, level of control of the risk and the perceived benefits from taking that risk. Sometimes it is necessary to accept increased risk in the short term to reduce risk in the long term. Waiting for a perfect solution can increase risk. Dose estimates need to be realistic, as pessimistic dose predictions can rule out good solutions.

FUTURE NUCLEAR POWER PLANTS IN EMBARKING COUNTRIES: THE CHALLENGE OF PREPARING FOR OCCUPATIONAL RADIATION PROTECTION

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Abstract

The United Arab Emirates has established a legislative framework for occupational exposure, in accordance with Requirement 2 of GSR Part 1. The implementation of this framework has been developed in line with the publication of the Nuclear Law and the establishment of the Federal Authority for Nuclear Regulation (FANR). FANR has produced regulations and guidance material in the areas of occupational radiation protection. FANR-REG-04 “Regulation for Radiation Dose Limits and Optimisation of Radiation Protection for Nuclear Facilities” includes number of Articles specifically directed towards occupational exposures in nuclear facilities. The emergency exposure situations are addressed in FANR-REG-12 titled “Emergency Preparedness for Nuclear Facilities”, in accordance with IAEA dose limits for workers in emergency preparedness and response. Strong safety culture is a key factor in optimizing the occupational radiation protection. Therefore, FANR has issued regulations that require licensees to take measures to continually develop and improve their nuclear safety and security culture. FANR has also adopted the IAEA recommendations on the attributes of a strong safety culture in its regulatory guidance.

INTRODUCTION

The UAE government established in April 2008, the “Policy of the United Arab Emirates on the Evaluation and Potential Development of Peaceful Nuclear Energy” (the Nuclear Policy). The Nuclear Policy was based on a study of viable options to meet future energy needs, and focused on the potential benefits of nuclear power for the UAE people, the environment, and the economy [2].

The Nuclear Policy makes the following commitments in the development of nuclear energy in the UAE:

- Complete operational transparency;
- Pursuance of the highest standards of non-proliferation;
- Pursuance of the highest standards of safety and security;
- Conformance to the International Atomic Energy Agency (IAEA) standards in evaluating and potentially establishing a peaceful nuclear energy programme;
- Development of peaceful domestic nuclear power capability in partnership with the governments and firms of responsible nations, as well with the assistance of appropriate expert organizations;
- Assurance that the peaceful domestic nuclear power programme is developed in a manner that best ensures long-term sustainability.

The UAE has moved forward on the commitments outlined in its Nuclear Policy through the adoption of the relevant international instruments for nuclear safety, security, and non-proliferation, and through the formal establishment of the Federal Authority for Nuclear Regulation (FANR) with Federal Law by Decree No 6 of 2009 and the Emirates Nuclear Energy Corporation (ENEC) with Abu Dhabi Law No 21 of 2009[2].

In December 2010, ENEC submitted its first application to FANR for a licence to construct the first two units of a nuclear facility at the proposed site of Barakah in the Western Region of Abu Dhabi. The application included a comprehensive Preliminary Safety Analysis Report (PSAR) based on the Shin-Kori Units 3 and 4 facility in Korea, for which the Korean authorities issued a construction permit in 2008, and which serves as the reference plant for the UAE [2].

In July 2012 FANR has granted ENEC a licence to construct two nuclear power reactor units at its proposed Barakah site in the Western Region of the Abu Dhabi Emirate and the reactors are under construction. Also, ENEC submitted the second application for the construction of the second two units Barakah units 3 and 4 to FANR on 1 March 2013 and it is under review.

FANR developed number of regulations and regulatory guides relating to the control and supervision of the nuclear sector. FANR has made significant progress in recruiting a qualified and capable workforce since its establishment to ensure the nuclear programme's human resource needs are met in the immediate, mid-term and the long term. Fifty-four per cent of FANR employees are Emirati citizens. The balance of the staff comprises expatriates with nuclear experience recruited from 23 countries around the world. The depth and breadth of expertise embodied within this team has been instrumental to FANR’s achievements to date. The diversity in FANR employees provided FANR with a broad perspective of the best operational radiation protection (ORP) practices, drawn from the lessons learned in other countries [1].

OVERVIEW OF THE ARRANGEMENTS AND REGULATORY REQUIREMENTS

The following FANR regulations related to occupational safety for nuclear facilities have been issued prior to the receipt of the construction application for BNPP:

FANR-REG-04 titled “Regulation for Radiation Dose Limits and Optimisation of Radiation Protection for Nuclear Facilities” sets out dose limits for occupational exposure and for members of the public. FANR-REG-04 also describes requirements for optimisation of protection for workers and the public so that the number of people exposed, and the magnitude of the individual radiation doses are as low as reasonably achievable, taking account of social and economic factors [1].

FANR-REG-06 titled “Application for a Licence to Construct a Nuclear Facility” requires an applicant for a construction licence to describe in its application preliminary information on the radiation protection programme including the design features of the facility, and preliminary information on the programme for pre-disposal management of radioactive waste [1].

FANR-REG-11 titled “Regulation for Radiation Protection and Predisposal Radioactive Waste Management in Nuclear Facilities” complements FANR-REG-04 by setting out requirements for radiation protection and predisposal radioactive waste management during the operation of nuclear facilities. FANR-REG-11 addresses the licensee’s responsibility in setting up a radiation protection programme as part of its management system covering the elements of organisational responsibilities, the classification of working areas and access control, local rules and supervision of work, work planning and work permits, protective clothing and equipment, workers' health surveillance, workplace monitoring and assessment of occupational exposures, training, and records [1].

FANR-REG-11 requires the licensee to identify and establish controls over all radioactive waste and to keep radioactive waste to the minimum practicable. This regulation also sets criteria for clearance from regulatory control and discharge of radioactive waste, and for an environmental monitoring programme [1].

FANR-REG-12 titled "Emergency Preparedness for Nuclear Facilities" specifies FANR's requirements for the licensee's preparation, planning for and response to emergencies at nuclear facilities. Its purpose is to ensure that the licensee has an organisation that is capable of coping with emergencies and mitigating their consequences, and that the licensee can perform assessment actions and implement notification procedures. This regulation also sets exposure limits of emergency workers.

CURRENT STATUS OF FANR RADIATION PROTECTION INFRASTRUCTURES

Another aspect of developing an ORP is obtaining the necessary radiation protection equipment and developing the infrastructure to support the required calibration and maintenance activities. The development of FANR's radiation protection infrastructures is in progress. The radiation protection infrastructure includes the Secondary Standards Dosimetry Laboratory (SSDL), Radiological Response Vehicle, Environmental Laboratory, Gamma Monitoring Network, and other programmes supporting Radiation Safety.

— SSDL

FANR has been nominated as the UAE participant in an IAEA Technical Cooperation (TC) project to support the establishment of an SSDL in the UAE. The SSDL is under construction and expected to be completed and fully operated by the year 2015. While a dosimetry programme must be established in the UAE, the UAE Government provides a personal dosimetry service through the Ministry of Health, Dubai Health Authority and a Government hospital and international providers of such services, which also operate in the UAE.

— Radiological response vehicle

FANR is procuring and configuring a radiological response vehicle as part of FANR's responsibility for the monitoring of radiation around nuclear facilities and for cooperating, providing advice, and information to relevant government agencies in relation to radiation protection and emergency planning and response.

— Environmental laboratory

FANR is co-operating with the Khalifa University (local university) in the field of environmental sample analysis. The lab is equipped with Gamma Spectrometry (HPGe Detectors), low background alpha and beta counter, liquid scintillation counter and preparation room. The lab would provide independent measurements of radioactivity in the environment and support radiological assessments during emergency by providing measurements of radioactivity in air, soil, food and water.

— Gamma monitoring network

FANR is coordinating with other competent authorities to establish arrangements for sharing real-time gamma dose rates across the UAE. Currently, FANR has procured twenty five Autonomous Gamma Stations (AGS), and seven stations have been installed around the UAE. FANR will install Gamma monitoring facility at the Barakah NPP site for continuous and real-time measurements.

— National dose register

FANR is in the process of establishing a national dose register, as required by the Nuclear Law (Decree No.6 of 2009) for maintaining and monitoring the dose records of all exposed workers in the UAE, to ensure that the licensees are complying with the FANR regulation for occupational dose, and to initiate the appropriate actions in case of non-compliance. Also, FANR is in the process of establishing an electronic dose register system to facilitate the dose tracking of all exposed workers.

IMPLEMENTATION OF RADIATION PROTECTION PROGRAMMES BY THE LICENCE HOLDERS

The design of the Barakah NPP incorporates radiation protection measures to ensure that occupational radiation exposures in future operation will be as low as is reasonably achievable (ALARA).

These measures include separation of radioactive components into separately shielded compartments; use of shielding designed to adequately attenuate radiation emitted from pipes and equipment that are sources of significant exposure; use of remotely operated equipment; ventilation of equipment areas that have the potential for creating airborne contamination; installation of permanent radiation monitoring systems; training of personnel in radiation protection; and development and implementation of administrative policies and procedures to maintain exposures as low as reasonably achievable.

Planning for an offsite radiation monitoring is in progress. ENEC submitted the preoperational Radiological Environmental Monitoring Programme (REMP) to FANR for approval in December 2012 and will collect background radiological data for two years prior to plant operation [1].

Radiation protection training and development are currently in progress within ENEC, and an employee training programme has been established to provide all employees with knowledge of the fundamentals of radiation protection. Future training of radiation workers that will require access to areas of potential radiation or contamination has been planned [1].

FANR has reviewed and accepted the information submitted by ENEC in the PSAR on the plant design aspects and the preliminary description of the radiation protection programme. Before granting an operating licence, FANR will review further submissions to verify that the final design, the operator's proposed radiation protection programme, and the arrangements for pre-disposal of radioactive waste comply with FANR regulatory requirements [1].

REGULATORY CHALLENGES

— Training

It is a challenge to maintain an adequate level of expertise and human resources in all areas of nuclear and radiation protection in the UAE. Indeed, FANR current high level of nuclear safety is critically relying on retaining and recruiting people with the necessary scientific competence. To guarantee the availability of suitably qualified personnel, who understand the facilities, equipment, processes and activities of the programmes they inspect and license, as well as the criteria, techniques and mechanics involved in inspection and licensing.

Since the beginning of 2009 FANR's Education & Training Department has been evaluating the Capacity Building needs of FANR staff, with a focus on creating and continuously developing the training programmes and options that will ensure the growth of skills and abilities of FANR's staff and especially involving UAE Nationals. In this regard, the following programmes have been developed:

- Scholarship Programmes;
- Secondment at Korea Institute of Nuclear Safety (KINS) and US Nuclear Regulatory Commission (NRC);
- RISKTEC Programme in UK;
- Gulf Nuclear Energy Infrastructure Institute (GNEII) at the Khalifa University;
- Institute of Radiation Protection and Nuclear Safety (IRSN); and
- International Nuclear Safeguards and Engagement Programme (INSEP).

Nuclear education and training schemes will be further harmonized and extended to meet FANR's and stakeholders' need in the areas of reactor systems, radioactive waste management and radiation protection. This will help to provide attractive opportunities for young people wanting to enter this field.

— Diversity

FANR is made up of people from many cultures and backgrounds. The diversity of cultures provided FANR with a broad perspective of best practices drawn from the lessons learned in other countries. However, it also presents challenges in the area of communication of ideas and viewpoints between people of different languages and cultures. The diversity of cultures and languages can provide rich learning opportunities among the workforce, since they have come from a mature nuclear culture, where the elements and supporting infrastructures are in place. It should be borne in mind that these elements may not yet exist and must be developed. It is a learning experience for personnel who have joined FANR to work in this environment, but FANR must also ensure that principles important to safety are maintained.

— Dosimetry service

The assessment of occupational exposure due to external radiation sources is an essential part in the ORP. In the UAE there are three dosimetry service providers. However, none of them is an accredited dosimetry service provider. FANR-REG-24 titled “Basic Safety Standards for Facilities and Activities involving ionizing radiation other than in Nuclear Facilities” requires the use of ‘an approved/licensed dosimetry services that operate under an adequate quality management system[3].

FANR-REG-24 does not apply to nuclear facilities; however, it states the requirement for an acceptable dosimetry service which is applicable to the nuclear facilities as well.

FANR does not provide approval or authorisation of service providers for individual monitoring. In its regulatory guide FANR-RG-007 titled “Radiation Safety Guide” FANR has indicated that it relies on formal approval by recognized radiological health authorities, such as approval by the Health and Safety Executive in the UK, or accreditation by the National Voluntary Laboratory Accreditation Programme (NVLAP) in the United States [3].

Furthermore, FANR has developed criteria to improve the monitoring and recording of occupational exposures in planned exposure situations and to be fulfilled by dosimetry services for the individual monitoring of workers subject to occupational exposure (i.e. external radiation).

FANR will have an IAEA mission on Occupational Radiation Protection Appraisal Service (ORPAS), in order to define an action plan for further development of the infrastructure for the monitoring of exposed workers.

CONCLUSIONS

The challenges to develop an ORP programme in an emerging nuclear country are vast and complicated. When overseeing a radiation protection programme, the regulator is responsible for ensuring the health and safety of the workers, public and environment. FANR has made significant progress in developing ORP infrastructure. FANR is continuing to improve its preparation for the operational ORP through issuing more regulations and regulatory guides, assure the implementation of ORP programmes by the licensees and maintaining an adequate level of expertise in the nuclear field.

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RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 10

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INTRODUCTION

The experience of past decades shows that Occupational Radiation Protection (ORP) programmes have been very successful in reducing the radiation doses received by workers during the operation, maintenance, and refuelling phases of nuclear power plants. These lessons have also been effectively applied across the whole range of nuclear facilities/ sites. Nonetheless, there remains the need to continue to investigate means of maintaining radiation doses to workers ALARA. The contributing papers of this session mainly focus on future challenges for strategic areas of ORP in the nuclear power sector, in order to bring clear benefit with different country perspectives, and provide valuable input for the implementation of new nuclear energy programs. The aim of this summary is to provide a review of the papers submitted by focusing on issues and themes that arise or are indicated. Seven papers presented in this session fall into the following groupings:

- Four papers on ALARA and dose reduction programs, its implementation and monitoring experiences;
- Two papers on occupational radiation exposure and source-term management, characterization with necessary technology;
- One paper on radiological impact of routine discharges.

DOSE REDUCTION THROUGH EFFECTIVE PROGRAMMES

Since the beginning of the 1990s, occupational exposures in nuclear power plant has strongly decreased, outlining efforts achieved by nuclear operators worldwide in order to maintain occupational exposure as low as reasonably achievable (ALARA) in terms of collective exposures and average individual exposures. These efforts have focused on both technical and organisational aspects and many international documents on ORP in fuel cycle facilities are available from international institutions or national initiatives for the implementation of key lessons learnt, effective communication during the life-cycle for optimization, balance of risk and allocation of resources and publicly recognisable effective ORP [1-3]. The collective opinion on the contributing papers is that:

- Collective radiation exposure should not be seen as the only indicator of the efficiency of ORP programmes at NPPs and new radiation protection indicators should be developed;
- Multi-disciplinary work environment (design engineers, operation, chemistry, maintenance, job planners, R&D, etc.) is enlarging, and needs further innovative approaches for sustainability;
- Source term management is still a topic of increasing interest, and it requires international feedback from the past experiences to guide the new regimes.

The paper from South Korea [1] provides important clues for a successful dose reduction plan with effective methods for steam generator replacement, removal of resistance temperature detectors (RTD) bypass lines, installation of tritium removal facilities, and zinc injection. KHNP is now preparing a new dose reduction plan based on the results of EPRI ALARA assessment and several on-going R&D projects. The paper from the UK [2] reports on a novel and consistent approach (CORE- Control of Occupational Radiation Exposure, regulatory inspection project) which has been developed for the full range of nuclear facilities. In addition to assessing the compliance of nuclear sites with relevant UK legislation, the project is also intended to identify any industry-wide themes that could be considered to be areas for improvement. A further, significant objective of the project is to identify examples of good practice, which will be communicated to site operators to consider adopting in their own arrangements [2]. The criteria for assessing the ALARA performance use dose constraints-like instruments, or at least the concept of dose constraints, for activities and facilities which is implemented in the regulatory framework in some countries. In particular to PWRs, the paper [3] points out at activated corrosion products, deposited on the surface of reactor coolant system and other equipment that are the main sources of doses, and summarize the findings of a project to improve knowledge of occupational exposure and its related source term in NPPs.

ORP MONITORING, STATE-OF-ART TECHNIQUES

Monitoring (surveillance) is integral part of the ALARA programme as indicated in number of papers (including refs [1, 2, 3 and 4]). The paper from India [4] indicates vast experience in providing radiological surveillance in each step of the fuel fabrication operation for the protection of workers and the work environment. ORP program, as indicated in this paper, is formulated by taking into account the absorption classes and the mode of radiation hazards associated with the processes. Work atmosphere monitoring and Personnel monitoring procedures and methodologies adopted at various stages of fuel fabrication process are elaborated.

Management of the primary system water chemistry has been, and still is, a major contributor to collective dose reduction programs at the nuclear power plants. It must be taken into account at all stages of the facility life: its design and commissioning (choice of material, design of clean up system), during its operation (operation chemistry, shutdown procedures, zinc injection, full system chemical decontamination, flushing) as well as during decommissioning (full system decontamination) [5, 6]. It is obvious that an optimized strategy requires involvement and collaboration among all stakeholders; mainly operation, radiation protection and chemistry staff, and a strong support from the management in order to cope with all operational priorities (e.g., shortening the outage duration). Benchmarking as well as inputs from advisory institutes may also play a key role. In order to assess efficiency of strategies to minimize contamination of the primary coolant, components and the associated radiation field generation, radiation protection staff may rely on various measurement techniques. Regarding the needs (area monitoring, purification follow-up, hot spots characterisation, etc.), proper selection of survey instrumentation (radiation survey meter, electronic dosimeters, germanium detector, CZT detector [5], remote and spectrometric techniques [6], etc.) is important to provide accurate dose rate readings at the intended measurement locations by taking into account all factors that may influence the data. A further message arising from the papers states that careful attention must be paid to the identification of point locations, considering plant specificities. For assessing the source terms over long time period, points must be clearly identified and remain constant over time. Measurement must be achieved with the same instrument and at the same time after shutdown to allow for relevant comparison and follow-up.

MANAGEMENT OF RADIOACTIVE RELEASES IN THE FRAMEWORK OF ORP

Comprehensive safety assessments including occupational exposure requirements are described in the regulations of numerous countries and policies of facility operators to estimate the potential exposures due to releases under operating conditions [7]. With the view of presented papers, implementation of a graded approach is recommended, to consider both the magnitude of the projected exposures in connection with the complexity of the operations at the nuclear fuel cycle facilities. Documentation of the decision-making process (supported by modelling tools) should occur, to ensure transparency of the process, and to facilitate the reviews of the prevailing circumstances in the future. The operating management of the facility is to make decisions regarding the design, structure, and implementation of the optimisation process that could analyse current discharge data, in order to arrive at a clear understanding of what may reasonably be expected from the new evolutionary plants.

CONCLUSIONS

The last two decades have been characterized by the substantial progress achieved in occupational radiation protection, as shown by the reductions of individual and collective doses. However, it has to be borne in mind that networking is an important element to enable collection and exchange of information regarding ORP over the full life-cycle. The development and execution of effective occupational radiation protection programmes cannot be accomplished without considering the other programmes that are simultaneously developed and implemented at nuclear power plants and other nuclear fuel cycle facilities. Many factors have contributed to the success of ORP programme and practical implementation of the ALARA principle, which requires the adoption of appropriate technical and organizational measures by the facilities.

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[7] NASSAR, N. et al., “Assessing the Possible Radiological Impact of Routine Discharge from Proposed Nuclear Power Station” (to be included in the conference proceedings).

CHAIRS' SUMMARY OF TOPICAL SESSION 10

The presentations and contributions in session 10 gave a good overview on occupational radiation protection (ORP) in different life cycle phases of a nuclear fuel cycle facility starting from the conception, through operation to decommissioning. Several conclusions can be drawn from the session. A first conclusion is that trends in occupational radiation exposure in nuclear fuel cycle facilities, available in UNSCEAR and ISOE databases, show a steady decrease of the annual collective dose and average individual doses. After an important decrease of the exposures in uranium mining about two decades ago, we see that nuclear power plant operation remains the main contributor to occupational collective dose within the nuclear fuel cycle. In average, the collective dose in nuclear power plants is still going down, however the reduction is less pronounced compared to the reduction seen twenty years ago. Different contributing factors have led to a general reduction of the collective dose. The evolution of radiation protection standards and the collaboration within the framework of international organizations such as ILO, IAEA, IRPA and NEA provided a solid base to efficiently implement the system of radiation protection. Within the industry, the markets for energy drive the utilities towards better and more efficient work planning and operations. The introduction of new techniques and design improvements are also identified as contributors to the reduction of exposures. In recent years we have seen technological improvements beneficial to individual dose measurement, dose management, radiation field measurement at the workplace, dose prognoses and robotics, all playing their role in the reduction of the exposure of the workers.

Another, and maybe one of the important factors is the efficient system, developed in nuclear industry, to distribute and exchange results from the feedback of experiences and peer reviews on safety and radiation protection. It is important to maintain and further improve this knowledge base, established by IAEA, NEA and ISOE, through different symposia involving experts from industry and regulatory bodies. A second conclusion is that the collective dose is still an important management tool that enables to evaluate the effectiveness of the ALARA approach in a nuclear fuel facility, year after year. Inter-comparisons with other similar NPPs are also possible, although care must be taken to account for possible differences in activities between facilities. It is understood that the collective dose is a good indicator to assess the evolution of the effectiveness of the ORP in a facility, however further information is needed on the detailed operations to clearly understand the trends in collective dose. It was identified that the ISOE system can provide all kinds of comparisons including typical dose rates at plant components and collective dose per worker groups. In the future, it could be beneficial to provide more additional data regarding the distribution of workers' individual exposures per dose intervals.

ALARA programs should stimulate and involve operating organizations to implement ORP improvements in work planning, operations or design. Experiences on the effectiveness of the ALARA programs are available and shared by the different utilities and are bases to identify elements for a continuous improvement.

A third conclusion is related to the importance of considering ORP already in the design of a facility. The Expert Group on Occupational Exposure (EGOE), established by the NEA and ISOE focused their attention on the integration of operational radiation protection in the design and conception phases of NPPs. This resulted in a practical guidance published as the report "ORP principles and criteria for designing new NPPs". The guidance includes experience from past designs, check lists and points of attention that can help in the design of new NPP's, in order to take into account ORP and ALARA in the design phase and avoid doses and cost related to operation.

It is clear that the involvement and authority of ORP experts within operating organizations, during the design and later phases, nuclear power plants is paramount to implement an efficient ORP program. This should be adequately recognized and requested within the framework of national regulation.

A fourth conclusion focuses on the countries embarking in the use of nuclear energy. The national regulatory bodies in the embarking countries face many challenges in preparing the framework for the occupational radiation protection. Establishing an ORP framework involves issuing regulations, guides and the implementation of ORP programs by the licensees. It also involves establishing and maintaining an adequate level of expertise in all domains of the nuclear field (nuclear safety, radiation protection, emergency preparedness). Again the framework of international organizations such as ILO, IAEA, IRPA and NEA can provide, together with the embarking countries, a solid base to efficiently implement the system of radiation protection.

The conclusion related to ORP in long term operation and decommissioning shows the importance of ALARA practices and an integrated risk approach. Good ALARA practice established already during design and operation of the plant are important for the overall planning of the decommissioning process and for its work control. Early integration of ORP experts in planning is always necessary and there is a clear need to compare planned and real doses in order to enrich the use of experience feedback in the planning.

It was noted in the data presented by the experts that the annual collective dose for the decommissioning of BWR/PWR decreased roughly by a factor of 10, with respect to the operational phase. This was mainly attributed to the removal of the spent fuel from the site and radiation fields due to full system decontamination. The presentation on ORP at a reprocessing plant (i.e. Sellafield) illustrated that this site copes with a wide range of different processes including construction, operation and decommissioning all side by side at the facility. A flexible approach in ORP and ALARA is essential as the facility spans already sixty years of operation and contains installation of different ages based on design standards that evolved through the years. Experiences given through practical examples show that the evaluation and the decision in the ALARA process is influenced by the individual's perception of risk, depending on experience/knowledge, level of control and perceived benefits from the operation performed. Sometimes it is beneficial to accept operations with a higher risk in the short term in order to reduce the risk in the long term. Waiting to find a perfect solution to perform an operation or to deal with an exposure situation can increase the risk in the long term. Overconservatism in the dose prognoses of operations can also lead to the elimination of good and practical ways to perform the operation. Confronted with different risks, the organisation should encourage a flexible and practical approach using a range of different techniques as needed to deliver an integrated risk reduction.

TOPICAL SESSION 11:

EDUCATION AND TRAINING IN OCCUPATIONAL RADIATION PROTECTION

Chairpersons: H. Schmitti-Hannig, Germany and A. Hammou, Tunisia

THE STATUS OF AVAILABLE RADIATION PROTECTION TRAINING THROUGH THE IAEA AND THE SUPPORT IAEA PROVIDES TO MEMBER STATES — DEVELOPING AN EDUCATION AND TRAINING STRATEGY FOR THE COUNTRY

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Abstract

The statute of the International Atomic Energy Agency includes the establishment of, and provision for, the application of safety standards for protection of health, life and property against ionizing radiation. IAEA assigns high priority to education and training in nuclear, radiation, transport and waste safety as one of the main mechanisms to facilitate the application of safety standards in IAEA Member States. The 'Strategic Approach to Education and Training in Radiation, Transport and Waste Safety, 2011-2020', provides the inspiring principles for IAEA's education and training activities in the area. Its ultimate vision is for Member States to develop a national strategy for education and training, considered to consist of four interlinked phases: analysis of the needs; design of; development and implementation of; and evaluation of the national education and training programme. For that purpose, the IAEA' Division of Radiation, Transport and Waste Safety is: developing a guidance to guide Member States in establishing a national strategy for education and training in radiation, transport and waste safety; developing and disseminating education and training material. Monitoring mechanisms have been established to evaluate Member States' status and achievements in the field.

INTRODUCTION

— Establishment and application of IAEA safety standards

The IAEA has a statutory function to establish standards for the protection of health, life and property against ionizing radiation and to provide for the application of these standards to peaceful nuclear activities. The IAEA's safety standards are not legally binding on Member States but may be adopted for use in the concerned national regulations and legislation. However, these standards are binding on the IAEA in regard to its own operations and on Member States whenever receiving assistance by the IAEA. Education and training activities supported and promoted by IAEA are aimed at fulfilling its statutory safety functions to support Member States in the application of the safety standards.

IAEA Safety Requirements on ‘Governmental, Legal and Regulatory Framework for Safety’ [1] recommend that Governments establish a generic national policy and strategy for safety, and that this should include, inter alia, the need and provision for human resources. As an essential element of the national policy and strategy for safety, the Governments shall make provision for building and maintaining the competence of all parties having responsibilities in relation to the safety of facilities and activities in order to make available a sufficient number of suitably qualified staff.

— IAEA strategic approach to education and training

The IAEA’s education and training activities in radiation safety follow the resolutions of General Conference; the highest policy-making body of the IAEA composed of representatives of all Member States, and reflects the IAEA safety standards [1-3]. They are developed in line with the general policy principles provided in the IAEA “Strategic approach to Education and Training in Radiation, Transport and Waste Safety, 2011-2020” [4], endorsed by the General Conference in 2010. The Division of Radiation, Transport and Waste Safety in the IAEA Department of Nuclear Safety and Security is responsible for the implementation of the IAEA strategic approach.

The ultimate vision of the IAEA Strategic Approach is “*for Member States to have established a sustainable education and training infrastructure that addresses national needs for building and maintaining competence in radiation, transport and waste safety, and is consistent with the Agency’s safety standards*”. In referring to Member States’ education and training infrastructure and its sustainability, one of the main objectives of the IAEA Strategic Approach is to facilitate the development and implementation of a national strategy for education and training for radiation, transport and waste safety in Members States.

NATIONAL STRATEGY FOR EDUCATION AND TRAINING IN RADIATION, TRANSPORT AND WASTE SAFETY

The process to establish a national strategy education and training in radiation, transport and waste safety consists of four interlinked phases, where the outcome of one phase is the starting point for the next phase, with the loop being closed by evaluation and feedback, as shown in Figure 1.

FIG. 1. Phases to establish a national strategy for education and training in radiation, transport and waste safety

The first phase in the process is the assessment of who needs education and training in radiation protection in the country. This assessment will entail:

- Collection of information about the current and reasonably foreseeable facilities and activities within the country;
- Analysis of existing national education and training requirements, such as those required by regulations or as part of professional qualifications; and
- Evaluation of the number of people within the identified facilities and activities that need to be trained and educated in radiation protection.

The second phase is the design of a national education and training programme that is based on the assessment carried out in the first phase. The programme should define the educational and training events that need to take place to ensure that all people identified in the first phase have the required level of education and training to enable them to perform their work in a safe manner that is in-line with (inter)national requirements, such as the International Basic Safety Standards [1].

The third phase is the development and implementation of the aforementioned national education and training programme. This might necessitate the development of new, or expansion of, existing educational/training mechanisms and infrastructure. An analysis of the current national status and capacity for delivering education and training events in radiation protection will first need to be undertaken to identify the gaps between what is available and what is needed. Where gaps are identified, decisions will need to be taken whether to develop the expertise/infrastructure nationally or to send people to other countries for their education/training.

As final step, it is important to ensure that the effectiveness of the national education and training programme be evaluated and monitored on a periodic basis. This will help to ensure that the State’s education and training programme continues to meet the national needs, recognizing that some initially identified needs may decrease over time while the need for refresher training will increase.

IAEA SUPPORT TO MEMBER STATES IN THE FIELD OF EDUCATION AND TRAINING

— Overview

IAEA provides direct assistance to Member States in the field of education and training in radiation, transport and waste safety at two main levels:

- By developing and disseminating guidance providing “A methodology for establishing a national strategy for education and training in radiation, transport and waste safety”;
- The guidance provides Member States with practical examples on how implement each of the four steps of the process to establish the national strategy (Figure 2a and 2b);
- By developing education and training material (including standardized syllabi with supporting material and documents) and by organizing educational and training events to disseminate and promote such material;
- The material developed and events organized by IAEA support Member States in the third step of the process to establish the national strategy, when developing and implementing the national education and training programme (Figs. 2a and 2c).

— Guidance to establish the national strategy for education and training

The guidance is primarily addressed to national bodies (e.g. regulatory authorities) and policy decision makers that want to develop and maintain competence and skills of personnel in radiation safety with an effective and sustainable approach by establishing education and training programmes based on the assessment of national training needs. Technical support organizations, education and training institutions, professional organizations, and other relevant stakeholders for education and training in radiation, transport and waste safety are also expected to be interested in the use of the guidance. Annexes are provided with practical examples on how to establish the national strategy.

Since 2012 eighteen (18) regional workshops were held under the IAEA Technical Cooperation programme in several languages (Arabic, English, French, Russian and Spanish) with more than 360 participants from about 90 Member States.

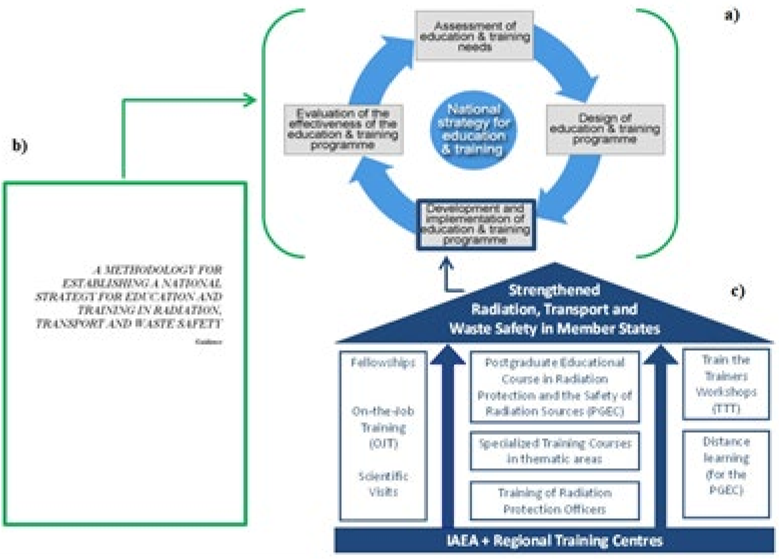


FIG. 2. Mechanisms and tools developed by IAEA to support Member States to establish a national strategy for education and training

— Competence building tools

a) IAEA Regional Training Centres for Education and Training in radiation protection

The IAEA's Division of Radiation, Transport and Waste Safety has developed a large portfolio of tools and mechanisms to build competence through education and training. The IAEA Strategic Approach assigned the IAEA Regional Training Centres (in Africa, Asia and the Pacific, Europe, and Latin America) a key role in the development of competence in the region, for example by hosting the Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (see 3.3.2), providing expertise for education and training in the area, and by collaborating with IAEA to disseminate the methodology for establishing a national strategy for education and training (see 3.2).

b) Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources

The Postgraduate Educational Course in Radiation Protection and the Safety of Radiation Sources (PGEC) is a comprehensive and multidisciplinary programme aimed at young professionals who may in later years become senior managers/decision makers with responsibilities related to radiation protection. The PGEC is based on a standard syllabus which has recently been updated to take account of new IAEA Safety Standards such as the revised IAEA Basic Safety Standards and to ensure it is consistent with ICRP's latest terminology. The PGEC also includes a module on 'Train the Trainers' as well as project work in which students are encouraged to do research or practical work that will be of direct benefit in their home country.

c) Specialized Training Courses in Thematic Areas

IAEA's Division of Radiation, Transport and Waste Safety has developed a large portfolio of training material for short duration courses (between 3 days to 6 weeks) on a range of subjects. Topics covered include, for example: regulatory framework; occupational protection; patient protection; radioactive waste management; transport of radioactive materials; and safety of radioactive sources. The courses are organized at both the national and regional level for various target audiences, such as: regulators; workers in industry, medicine and research; and medical staff.

d) Training for Radiation Protection Officers

The Radiation Protection Officer (RPO), according to the IAEA Basic Safety Standards, is a person technically competent in radiation protection matters relevant for a given type of practice who is designated by the registrant, licensee or employer to oversee the application of relevant requirements. Noting the key role played by the RPO, IAEA is developing a syllabus for training RPOs, based on foundation and practice-specific modules including suggestions for practical sessions, demonstrations, laboratory exercises, case studies, and technical visits to re-enforce the theory.

e) Training the Trainers

The Train-the-Trainers (TTT) modality is aimed at developing communication skills as well as familiarizing participants with IAEA training material with a view to building a core of national trainers in radiation protection. The training material includes presentational and communication skills, organization of training events and practical exercises. The TTT course is designed to be interactive with an emphasis on presentations being by the participants. TTT workshops for radiation protection officers have been run around the world at both national and regional levels.

f) Distance Learning

Distance Learning is a learning process undertaken under conditions where the learner and instructor are separated by distance and/or time. Distance Learning may involve the use of computer systems, the Internet, radio or television broadcasts, video presentations and correspondence courses. The IAEA Division of Radiation, Transport and Waste Safety have adopted the Distance Learning approach to deliver the pre-training course for the PGEC. The pre-training material, originally developed in slides by the United States Nuclear Regulatory Commission, has been adapted to be delivered through the IAEA's Cyber Learning Platform for Nuclear Education and Training (CLP4NET). The aims of the pre-training course are:

- To refresh the knowledge of the participants with basic and relevant subjects to facilitate their attendance at the PGEC; and
- To identify the areas where the participants might need further support.

The pre-training course has four modules on fundamentals, namely; biology and radiation effects, chemistry, mathematics, and health physics. Each module includes basic topics that are key and relevant to radiation protection and the safety of radiation sources. At the end of each module, a test is available to verify the level of knowledge of the attendee.

g) Fellowships, On-the-Job-Training, Scientific Visits

Fellowships are normally awarded for periods of up to one year, and in certain cases, extensions for further periods may be considered. These fellowships are available to university graduates or their equivalent, and to individuals at technician level in the requested field, mainly through project-oriented training. On-the-job training is provided to individuals by means of IAEA fellowships that are typically one to three months in duration. Such fellowships enable individuals to work alongside experienced professionals in well-established organizations with the purpose to get a practical experience and gaining specific skills for a certain methodology or process. Scientific visits are awarded to senior staff for the purpose of studying the development of radiation protection and safety, organizational aspects and function of training providers, training programmes and schools in radiation safety, and observing research activities. These awards are intended to broaden the scientific or managerial qualifications of specialists in developing countries. The duration does not exceed two weeks.

— Monitoring Member States' status and achievements

In order to collect, analyse and view the information regarding the national infrastructure for radiation, transport and waste safety in Member States, the IAEA Division of Radiation, Transport and Waste Safety has developed a web-based platform, RASIMS (Radiation Safety Information Management System). It provides a tool to evaluate the compliance of national legations and regulations with the IAEA Safety Standards.

Information from 135 Member States is presently available in RASIMS, grouped into six Thematic Safety Areas (TSA) to ensure that all aspects of the relevant IAEA safety standards are covered in a comprehensive and consistent manner.

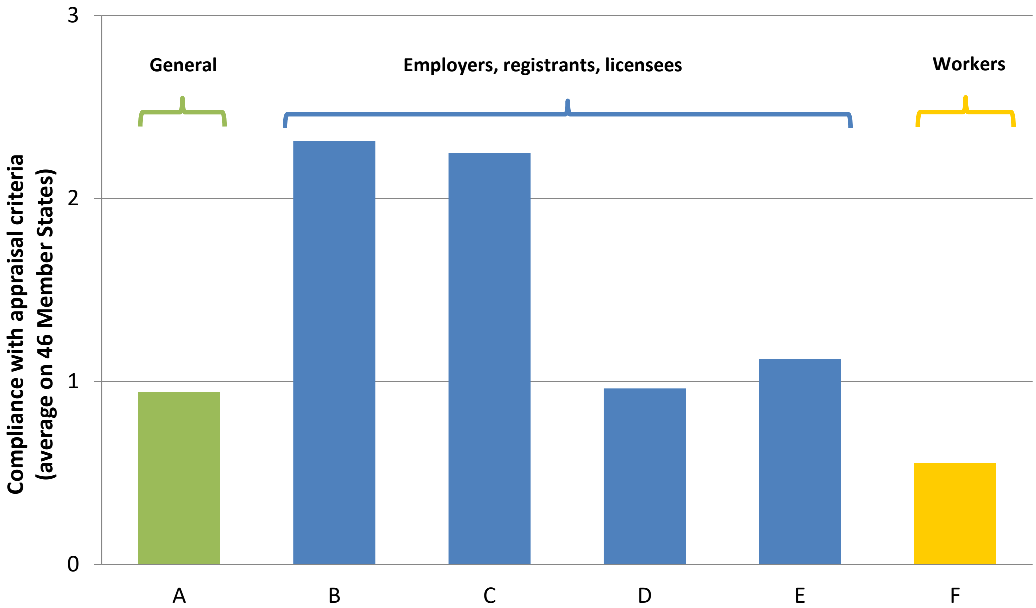
TSA6 is the specific area focusing on education and training in radiation protection and safety, structured to collect the information on:

- The legal and regulatory framework for education and training; and
- The establishment of the national strategy for education and training.

So far, information for TSA6 has been collected and analysed for 46 Member States. As the establishment of the national strategy for education and training is a task the Member States have just started addressing through the participation in the regional workshops held under the IAEA Technical Cooperation programme (see 3.1), few information is currently available in this area. On the other hand, the need of a legal and regulatory framework for education and training is being addressed since a longer time by Member States; thus, extensive information has been already collected in this area.

Fig. 3 shows the level of compliance of the national legal and regulatory framework for education and training of workers with some basic criteria, based on the requirements provided in the IAEA Safety Standards. Requirements were grouped into ‘general’ (education and training requirements for all the personnel working with ionizing radiations), specific requirements for ‘employers, registrants and licensees’ to train workers, and for ‘workers’ to accept and attend the training.

In the sample of 46 Member States, requirements are established to ensure that employers, registrants and licensees provide training to workers, particularly for those occupationally exposed. Less frequently requirements are established to ensure that employers, registrants and licensees provide training to restrict potential exposures, and keep records of training of personnel. Finally, national requirements are seldom established to assure that workers accept information, instruction and training in radiation protection and safety.



Level of compliance

“3”: full compliance; “2“: partial compliance; “1”: no compliance but actions taken; “0”: no compliance.

Appraisal criteria

A. National general requirements established for education and training of all personnel (including workers)
B. National requirements assuring that employers, registrants and licensees ensure that all personnel engaged in activities relevant to protection and safety have the appropriate education
C. National requirements assuring that employers, registrants and licensees provide appropriate training to occupationally exposed persons
D. National requirements assuring that registrants and licensees provide workers with the information, instruction and training necessary to restrict potential exposures
E. National requirements assuring that registrants and licensees maintain for a period as specified by the regulatory body and shall make available, as required, the records of training of personnel in radiation

FIG. 3. Level of compliance with appraisal criteria (average on 46 Member States) - (as per November 2014)

DISCUSSION AND CONCLUSIONS

The establishment by Member States of a national strategy for education and training in radiation, transport and waste safety, in line with the requirements as given in the IAEA safety standards, is one of the main challenges that will be faced to create a sustainable education and training infrastructure in this area. The IAEA's Division of Radiation, Transport and Waste Safety is supporting Member States by: providing advice on strengthening the legal and regulatory framework for education and training in radiation protection and safety, in compliance with the IAEA Safety Standards; developing guidance to establish a national strategy for education and training; and developing and disseminating education and training material.

Monitoring Member States' status and achievements is fundamental to provide a more effective support to Member States (e.g. designing projects and implementing activities addressed to Member States' specific needs) and to optimize the use of IAEA and Member States' resources. For that purpose, Member States are always invited to provide and update the information in RASIMS. The analysis of the information provided in RASIMS for TSA6 for a sample of 46 Member States, specifically in relation to the training of workers, showed that good progresses were made towards the compliance with the IAEA Safety Standards, particularly for what concerns employers, registrants and licensees' responsibility to provide workers with training in radiation protection and safety. However, further efforts are needed to strengthen the legal and regulatory framework for education and training, and above all for the establishment of a national strategy.

Noting that the prime responsibility and 'ownership' for developing competence through education and training lies with the individual Member States, IAEA's Division of Radiation, Transport and Waste Safety stands ready to provide the necessary assistance, including the development of further guidance, provision of expert missions, and organization of appraisal services.

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NUCLEAR REGULATORY AGENCY — 30 YEARS BUILDING COMPETENCIES IN RADIOLOGICAL PROTECTION IN LATIN AMERICA — FOCUS ON OCCUPATIONAL RADIATION PROTECTION

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Abstract

This paper aims at emphasizing the work made by the Nuclear Regulatory Authority (NRA) to build competencies in the area of Radiological Protection and Nuclear Safety. There are also explained the steps followed to turn Postgraduate Courses into Specialization Careers of the Buenos Aires University. The benefits offering for the internal demand and to Latin America and the Caribbean due to the higher academic degrees are pointed out. There are also stated the future goals to be met by the Regional Training Centre sponsored by IAEA and managed by NRA in Argentina.

INTRODUCTION

Argentina has been engaged in training and education for more than fifty years, building competencies in Radiological Protection and Nuclear Safety. The Nuclear Regulatory Authority (NRA) is one of the Regional Training Centres (RTC) for the Latin America Region. This RTC is the first and unique in Spanish language. The achievement of experiences in Education and Training initiated soon after the creation of the National Atomic Energy Commission (NAEC) in the 1950s. Together with the foundation of this relevant institution, devoted to the research and development of the atomic energy, the radiation protection discipline was conceived and born accompanying the pacific uses of the atomic energy. The radioprotection was internalised by the nuclear community as a need and a must.

At the very beginning, the radiation protection knowledge was applied internally, in the NAEC laboratories, but when the use of radioactive sources for medical treatment and diagnostic or for industrial uses has dramatically increased, it spreads all over the organizations and institutions, public or private through specialized training courses organized by the NAEC.

The regulatory branch of the NAEC kept the control of the use of ionising radiation until 1994 when the National Nuclear Regulatory Entity was created as an independent organization separated from the NAEC, which was considered as the “mother organization”. Afterwards, in 1997, the National Law 24804 known as the Nuclear Activity Law established the definitive independence of the Regulatory Activity from the promoter and created the Nuclear Regulatory Authority (NRA).

The Education and Training activity for safety purposes was clearly instituted as a strategic activity within the functions of the Nuclear Regulatory Authority.

SPECIALISATION CAREER AT ARGENTINA

The current *Specialization Career on Radiological Protection and the Safety of Radioactive Sources*, delivered by the Nuclear Regulatory Authority in partnership with the Buenos Aires University with the support of the International Atomic Energy Agency (IAEA) has a 37 years history. Initially, in 1977, with some experience gained on research and development, emerged the necessity of selecting professionals devoted to the nuclear activity on radiological protection issues and so started to progress the idea to create a specific course only to satisfy the internal demand. That course should have been shaped and adjusted to the resulting needs for that time being. By the 1980s the prestige of the Argentinean initiative was recognized by the IAEA which decided to offer its support. Since then Argentina and the Agency worked together and this support enabled to extend Education and Training to other countries that were initiating nuclear activities. So, the initial internal course designed by professionals working at the Nuclear Atomic Energy Commission, offered the bases to develop the Syllabus of the International Post Graduate Educational Course on Radiation Protection and the Safety of Radioactive Sources (PGEC-RPSRS) that was promoted by the IAEA over the world. The former postgraduate course and the latter specialization career were very well focused on the occupational radiation protection matters. Along the eighteen subjects of the recently created specialization career, topics are developed on the biological effects produced by the ionising radiation, the principles of the radiological protection and its international framework, the evaluation on external and internal radiological exposition, the technology used for radiological protection purposes and safety of the radioactive sources, the radiological protection of workers, public, patients, and at special facilities, such as radiant therapy, radio diagnosis, industrial radiography, nuclear medicine, production plant for radioisotopes, etc. Besides, as the career was created with a practical scope, many training activities involving measurement are performed in the field. Also, many technical visits have been carried out to installation of interest. The approximate time percentage of the total duration of the career dedicated to developing the occupational radiation protection thematic is about 60%. From 1981 to 2014, the Argentinean PGEC has produced more than 1000 specialized professionals in the region. Forty five percent (45%) of them are Argentinean. Most of them have reached the highest positions at the regulatory bodies in their countries.

The same happened with professionals attending the Postgraduate Educational Course on Nuclear Safety (PGEC-NS). The current *Specialization Career on Nuclear Safety*, established at the same year when the third Argentinean Nuclear Power Plant, Atucha II, was commissioned. This Career is the successor of the Post Graduate Educational Course on Nuclear Safety that started to be delivered in the year 2003, when it was decided to divide the initial *Radiological Protection and Nuclear Safety Postgraduate Course* into two, due to the fact that some countries in the region without nuclear activity only asked for Education and Training in the Radiological Protection area. The syllabus of the new Career follows the Basic Professional Training Course on Nuclear Security (BPTCNS) of the IAEA. There were produced 674 professionals up to 2014 in the area, of which 391 were Argentineans (i.e. 58 % of the total). For taking up this specialization career it has been accepted that participants who have finished the *Specialization Career on Radiological Protection and the Safety of the Radioactive Sources*, can justify equivalent specialisation. In order to strengthen the occupational radiation protection concepts, parts of radiological protection were selected for nuclear plants, in which the main contributors to the occupational doses are discussed along with the environmental monitoring inside and outside the plant, management and the transport of spent fuel elements into the storage, decommissioning activities, and each activity developed in nuclear power plants or in research reactor that may result in occupational doses. The approximate time percentage of the total duration of this career training is about 30%, without considering the basic concepts required.

Radiological Protection Course for Technical Level started in 1983, not only for professionals, but also for non-professional who proved in admission exams a sufficient background. This course is aimed at operational approach with emphasis to occupational radiation protection required e.g. for obtaining a license as a radiation protection officer, or just to get practical knowledge to cope with the daily work safely.

This is a full time 10 weeks course and it also receives, participants selected by the IAEA. This course has started in 1983 and about 700 total participants have taken up this training up to 2014. It is important to highlight that due to the increase of nuclear activity in Argentina, it became necessary to offer this course twice a year.

This course included, among others, biological effects of ionising radiation, the principles of the radioprotection, the occupational radiological protection, the radiological protection to the public and patients and different applications of radioactive sources.

The approximate time duration of this technical level course is about 35%.

— General Comments

The University of Buenos Aires employs, experienced specialists, who are working in the NRA and in the Faculty of Engineering for lecturing and this University grants the diplomas and certificates.

PERMANENT COMMITMENT OF THE NUCLEAR REGULATORY AUTHORITY TO EDUCATION AND TRAINING ACTIVITIES

In June 2006, Argentina received with success the first international Education and Training Appraisal mission (EduTA). The objectives of the Appraisal were to evaluate the national infrastructure for education and training in radiation protection which implied to revise:

- Legislative and regulatory framework related to education and training;
- Guidance material relevant to education and training;
- The education and training program for Regulatory Body staff (qualifications, training received to date and planned for future);
- The national training program in radiation safety or similar document;
- Approved /accredited training course providers /centres and /accredited training courses, if approval/accreditation procedures/systems exist;
- Annual reports from accredited training course providers/centres;
- Recognition/ approval/ accreditation procedures for education and training providers;
- Courses held in the past calendar year and the numbers of participants attending;
- Education and training programs for the five thematic safety areas;
- List of education and training events planned; and
- Feedback from the conducting of EduTA with emphasis on self-assessment.

Another objective was to identify the training needs and to prepare an assessment report including conclusions and recommendations for strengthening the national infrastructure for radiation protection training in Argentina.

Other countries that already participated in the EDuTA mission were countries illustrated in Fig, 1.

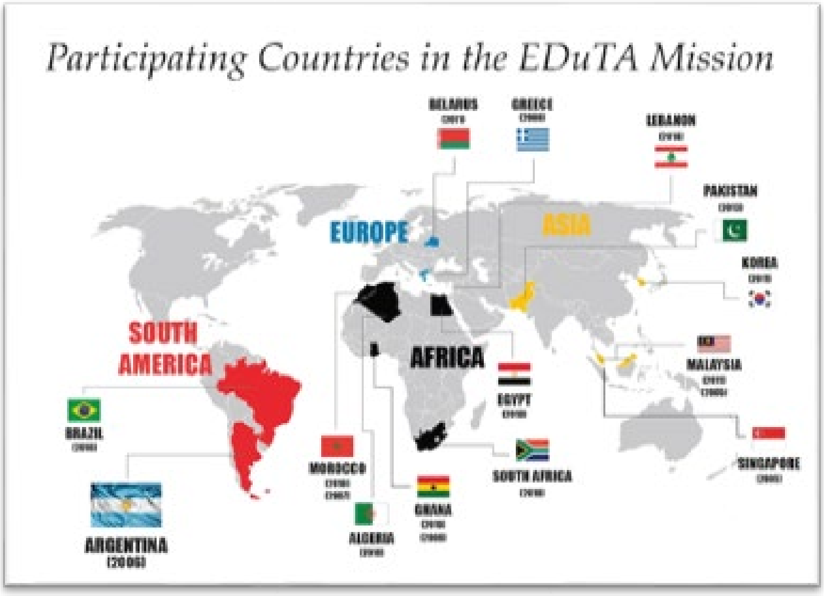

FIG. 1. Countries participated in the EDuTA mission

As a result of the successful international evaluation in September 2008, Argentina signed a long term Agreement with the International Atomic Energy and Argentina became the first Regional Training Centre (RTC) for the Nuclear Safety, Radiological Protection, Transport and Waste of Nuclear Material for the Latin America Region and the Caribbean. The Nuclear Regulatory Authority is in charge of the management of that RTC.

In the year 2006, the Argentinean Government announced the State decision to increase the development of the nuclear activity in the country. The Nuclear Regulatory Authority started to face new challenges and the growing demand of trained personnel.

The Education and Training Unit (E&T Unit), reporting directly to the NRA Board of Directors was created in 2010. The objectives of the E&T Unit are to manage and contribute to the improvement of the RTC, contribute to the establishment of a strategic internal plan for E&T of the personnel working in the NRA and to assure the preservation of specialized knowledge in the regulatory body.

THE TRANSITION FROM POST GRADUATE COURSES TO SPECIALIZATION CAREERS OF THE BUENOS AIRES UNIVERSITY

In the year 2011 the NRA through its E&T Unit, started to carry out a very ambitious objective, namely to elevate the academic framework of the post graduate courses on radiological protection and nuclear safety and so to produce joint presentations together with the Engineering Faculty for the Academic Board of the Buenos Aires University (BAU).

As a result, the Post Graduate Course on Radiological Protection became a Specialization Career at the Buenos Aires University on the 8th May 2012. In November 2013, the same achievement was obtained for the Post Graduate Course on Nuclear Security. So the first module of the *Specialization Career on Radiological Protection and the Safety of the Radioactive Sources* was available in the year 2013 and the first module of the *Specialization Career on Nuclear Safety* was created this September 2014.

FURTHER GOALS

The NRA is fully committed to contribute with the IAEA E&T strategy for the period 2014-2020 and is dedicated to enhancing the offer and to improve the quality of its training activities.

Besides, the Nuclear Regulatory Authority (NRA), through its E&T Unit is facing other important goals. One of these objectives is to contribute to develop a Technical Support Organization (TSO) in association with the prestigious public university to assist the NRA in particular and complex regulatory activities. There is also a strong possibility to start working in the development of a new specialized course/ career involving the other regulatory branches which are of legal responsibility for the NRA: Non-Proliferation, Safeguards and Security. We are proud of being pioneers in building competencies in Radiological Protection and in Nuclear Safety, for Latin America and the Caribbean and we are looking forward to improve and expand our offer. In addition, it is very important to go on contributing with the IAEA to the specialised strategy for the period 2014-2020 with a strengthened Regional Training Centre.

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ACHIEVEMENTS AND CHALLENGES IN RADIATION PROTECTION EDUCATION AND TRAINING TANZANIA'S PERSPECTIVE

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Abstract

The provision of any education program in Tanzania is subject to approval of national accreditation bodies. These are the Tanzania Commission of Universities (TCU) for a university degree related programs and the National Council for Technical Education (NACTE) for other programs. On the other hand, the provision of radiation protection training program is governed by the Atomic Energy Act 2003 and Atomic Energy (Protection from Ionizing Radiation) regulations, 2004. Since 1980s, the country has been striving to improve the radiation protection education and training program using internal and external resources. Despite some notable achievements, major challenges still exist. These include limitations in regulatory requirements, limited certification/accreditation, limited structuring of programmes as well as inadequate physical and human capacity, along with the preservation of nuclear knowledge. Considering required characteristics of education and training program in radiation protection and its current status, it can be concluded that the situation needs improvements in order to be of adequate quality and sustainability.

INTRODUCTION

The existing potential for radiation risks in several practices involving ionizing radiation has demanded a structured and systematic education and training (E&T) programs in radiation protection. Therefore, many international and national organizations have recognized this need and some guidance has already been issued [1, 2]. In Tanzania, the provision of any education program is subject to approval of national accreditation bodies. These are the Tanzania Commission for Universities (TCU) for university degree related programs and the National Council for Technical Education (NACTE) for other programmes. Currently, TCU's register comprises of 61 accredited institutions (28 being universities), while the NACTE is accrediting 81 institutions, most of which do not provide radiation protection education. The requirements for the provision of any training program are prescribed by the relevant legislation. For example, training in radiation protection is governed by the Atomic Energy Act 2003 and Atomic Energy (Protection from Ionizing Radiation) regulations, 2004. Under this regulatory framework, the Tanzania Atomic Energy Commission (TAEC) is empowered to formulate and implement programs for training of radiation safety officers, workers, employers and licensees in radiation protection matters. The United Republic of Tanzania encouraged the establishment and implementation of the national education and training programs in radiation protection. While some achievements have been recorded, a number of challenges have also been experienced. This paper presents the national status of education and training on radiation protection and the efforts being undertaken to overcome some practical challenges.

STATUS OF EDUCATION AND TRAINNG PROGRAMS IN RADIATION PROTECTION

— Education programs

There are limited national education programs related to radiation protection. However, some institutions include modules related to some extent to radiation protection in their curriculum. The list of existing education institutions with the course(s) shown in brackets is as follows:

- University of Dar es Salaam (M. Sc - Physics);
- Muhimbili University of Health and Allied Sciences (M. Med. (Radiology - B.Sc Radiotherapy, Diploma in Diagnostic Radiology);
- Kilimanjaro Christian Medical Centre, Ministry of Health (Advanced Diploma in Radiology);
- Tumaini University (M. Med (Radiology);
- Catholic University of health and Allied Sciences (Diploma in Diagnostic Radiology).

A survey of these institutions indicates that there is no education program directly related to radiation protection. The contents of the programs are limited even in a few institutions with radiation protection modules. For instance, no practical exercises are available, and they have limited professional accreditation.

— Training programs

As already pointed out in section 1, TAEC is responsible for organizing or facilitating the conduction of training courses in radiation protection. In additional to their main academic qualifications, TAEC trainers have been trained through the IAEA's training program (i.e. postgraduate courses, fellowship training, short training courses, scientific visits and expert mission services). TAEC has been organizing different types of training courses since 1980s, some with the assistance of external partners, e.g. IAEA, US Department of Energy, US Nuclear Regulatory Commission etc. The list of these training courses is as follows:

- Training course for radiation safety officers;
- Radiation Protection in industrial radiation facilities;
- Radiation protection in diagnostic radiology;
- Nuclear Security for national front line officers (NFLOs) and Mobile expert service team (MEST);
- Radiation protection in safe handling and security of radioactive materials;
- Radiation protection in mining practice; and
- Radiation protection in baggage x-ray screening facilities.

ACHIEVEMENTS AND CHALLENGES OF EDUCATION AND TRAINING PROGRAMS IN RADIATION PROTECTION

The following can be described as the achievements of education program in radiation protection:

- Availability of Nuclear Science and Technology Policy (2013): gives the direction of nuclear science and technology (NST) education and related manpower requirements. The national strategy to implement this policy is being finalized.

- Involvement of regulatory body in syllabi designing/ reviewing: There is a positive recognition of regulatory body during the designing/reviewing of some syllabi for example at colleges of medical radiography.
- Existence of a few educational programs: There are a few institutions that offer education programs related to radiation protection.
- Availability of a few competent academic staff: There are a few trained academic staff members in radiation protection related fields, e.g. medical physicists, radiation oncology, radiology etc. at institutes offering radiation protection related education.
- Despite these achievements, the following challenges have been experienced:
- Limited regulatory requirements on radiation protection education: Regulations are unsatisfactory on the requirements of radiation protection education in terms of organization, implementation and quality assurance.
- There is a limited number of institutions with radiation protection education to match the national needs.
- Inadequate radiation protection content in academic syllabi: Some institutions have syllabi with some kind of radiation protection content. However, the majority of syllabi is not updated and are not consistent with international standards.
- Limited accreditation and/or certification: Although some institutes, delivering courses related to radiation protection, are accredited by TCU or NACTE, they are limited in professional accreditation. Individual professional accreditation or certification of the majority staff members is also lacking.
- Inadequate preservation of nuclear knowledge: Like in many countries, the radiation protection workforce in Tanzania is also aging. There have been attempts to strategize on succession plans for a few trained personnel, but the success of these plans is still at initial stages.

— Training programmes

The national situation is similar to that in education programs. The achievements can be summarized as follows:

- Training requirements are backed by Regulations and therefore can be enforced;
- The national training program exists, which contributes positively to the awareness on the regulatory requirements; and
- There are a few available trained personnel, as well as basic equipment to support training programs.

In addition, there are also the following challenges:

- Inadequately structured training program: the selection criteria for trainees' have not been specified, the evaluation of courses was not objective, there is a limited coverage of practical exercises and re-training programs, variation of trainers' knowledge and experience of trainers also varies.
- Limited coverage of trainees: A few workers get an opportunity to participate in training courses and there are no local training courses for staff in radiotherapy and nuclear medicine.
- Limited awareness of employers and licensees: Due to the limited awareness on the benefits of these courses, some employers/licensees are reluctant to send their workers for such training.

- Some limitations in regulatory requirements: Regulations recognizes trained persons as qualified experts, which contradicts with the standard definition of a qualified expert. Also, it appears that a better arrangement would be to keep the provision of training course outside the regulatory authority, just as is the case for other technical services
- Lack of accreditation: The national training program in radiation protection is not accredited. The lack of accreditation tends to make training non formal and this consequently reduces morale of trainees, since certificates that contribute to career development are preferred over to certificates of attendance.

DISCUSSIONS

The characteristics of a desirable education program in radiation protection are described elsewhere [3-6]. Good policy, strategy, vision and mission are needed in order to reach its goals. The capacity to deliver radiation protection programmes, which is assured by quantity and quality of teaching staff, should be available. The training curriculum should be sound and it should be characterized by developed quality criteria to ensure robust output from the programme. A good training program in radiation protection should also possesses additional key attributes, such as structured modules that fit the background of trainees, consisting of theory, as well as of practical applications. Quantitative evaluation, sound accreditation and qualified trainers are also desirable to ensure quality of the training. Therefore, it can be noted that the status of radiation protection education and training program in the country exhibits many challenges if compared to the generally accepted requirements. Major challenges exist in the regulatory requirements, certification/accreditation, limited structuring, as well as in inadequate physical and human capacity. Despite the existing challenges, an improved situation is foreseen in the future, following the initial efforts to establish the Tanzanian Network for Nuclear Education, Science and Technology (TAN-NEST), based on the standard requirements [6].

CONCLUSIONS

The status of education and training programme in radiation protection in Tanzania has been presented. Considering desirable characteristics of education and training program in radiation protection and its current status, it can be concluded that the situation needs improvements in order to be of adequate quality and sustainability. The commitments of the government, universities, training institutes and other key stakeholders are necessary to make the dream of TAN-NEST to come true for an improved national education and training program.

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THE ROLE OF PROFESSIONAL SOCIETIES IN PROMOTING RADIATION PROTECTION EDUCATION AND TRAINING

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Abstract

One of the main strategic goals of IRPA is to promote excellence in radiation protection professionals. Pursuing this objective, IRPA has developed “Guiding Principles for establishing a radiation protection culture”, as well as an action plan on education and training (E&T). It is recognized that E&T is one of the ways to impact on radiation protection culture and to advance on its way. The role that IRPA Associate Societies can play in fostering RP culture through E&T activities is discussed: in this sense, the main lines of action include to promote coordinated activities, to stimulate contributions to the IRPA database on E&T events and resources, to encourage the creation of E&T networks sharing language or regional proximity to organize activities and to promote integration of young professionals and scientists in the new IRPA young professionals network.

INTRODUCTION

The International Radiation Protection Association (IRPA) is the international voice of the radiation protection profession. Radiological protection practitioners belonging to regulatory bodies, industry, medicine, research, universities, etc., join IRPA through national or regional Associate Societies (AS). Current membership is about 18,000 individual members from 64 countries belonging to 51 AS.

The defined Mission Statement of IRPA states that “it promotes excellence in the practice of radiation protection through national and regional AS and radiation protection professionals by providing benchmarks of good practice and enhancing professional competence and networking”. Also, that “it promotes the application of the highest standards of professional conduct, skills and knowledge for the benefit of individuals and society”. As part of its current Strategic Plan, IRPA has declared the following Vision: “IRPA is recognized by its members, stakeholders and the public as the international voice of the radiation protection profession in the enhancement of radiation protection culture and practice worldwide”.

The essential role of Education and Training (E&T), as a key factor to reach professional excellence, has been recognized since the beginning of IRPA. In the current IRPA Strategic Programme for 2012 – 2016, continuing priorities include the following:

> “To embed the sharing of good practice and professionalism in Associate Societies and individual members through the development of Guiding Principles, the support and coordination of education and training and the convening of effective meetings and Congresses”, as well as

"To increase the efforts of IRPA to support young practitioners and scientists in their work in radiation protection, in their education and training, and in their efforts to become members of the radiation protection community".

In order to effectively develop these objectives, IRPA has created a Task Group on E&T, as well as the Young Professionals Network. However, there is still a wide variation between different countries with regard to E&T methods as well as certification and recognition systems for radiation protection professionals and the desirable harmonization is still to come. Therefore, a Task Group on Certification of Radiation Protection Expert has also been created.

As part of its strategic goal to "promote excellence in radiation protection professionals", in the last years IRPA has developed "*Guiding Principles for establishing a radiation protection culture*" [1], as well as an action plan on education and training (E&T). Both are intended to be used by the IRPA associate societies in enhancing RP culture and practice in line with the aspiration of the Vision statement. They are described below.

THE IMPORTANCE OF EDUCATION FOR ESTABLISHING A RADIATION PROTECT ION CULTURE

The IRPA "*Guiding Principles for establishing a radiation protection culture*" [1], have been developed in an inclusive and consultative approach involving all the relevant stakeholders. They recognize that E&T is an essential way to impact on radiation protection culture and to continuously improve it. Radiation protection culture is a stabilizing factor for the organizations then, continuous learning allows a proper sharing of competence, looking for new and better radiation protection methods.

In developing radiation protection culture, E&T is an effective way to impact RP culture and has a key role to enhance the level of consciousness about radiation dangers for oneself and for the others, and to better understand the harm of ionizing radiation to the health, including knowledge about the effects of low doses. E&T contribute to maintain and increase a high level of RP culture by a continued proactive updating on the evolution of scientific knowledge and related judgments of relevance in RP; raising awareness among people directly or indirectly involved in RP; making sure that all radiological aspects are well known to workers, and everybody has the correct training to take care, prevent unnecessary exposure and evaluate RP aspects; emphasizing that radiation protection culture is not an established area of knowledge, but one of continuous change and update, not only in its contents, but also in its approaches, thus requiring permanent training.

Training should be undertaken and updated periodically, and testing done to evaluate its efficacy. As a general rule, it can be assumed that the usual ways to establish and improve levels of culture include continuous educational processes, access to multimedia (e-learning, applied games, etc.), and effective communication amongst workers, between directors / managers and workers, and between workers, patients and the public. Continuous learning allows a proper sharing of competence, looking for new and better RP methods. Learning through E&T from events, incidents and near misses is also an important part of RP culture development.

It is underlined in the Guiding principles that "Radiation protection culture is a learned way of life". It is obvious that a way of life should start with a proper education, and thus a conclusion is that RP culture must be present in all academic curricula on radiation applications. IRPA AS can check this aspect and otherwise act with the academic or regulatory authorities to ensure it is duly considered.

IRPA ACTION PLAN ON EDUCATION AND TRAINING

Given the nature of IRPA as association of national and regional professional societies, the IRPA E&T Plan aims towards promoting, supporting, providing guidance and networking to the E&T activities organized by the AS individually or, preferably, in cooperation.

IRPA AS are not universities and their E&T activities are not intended for an academic diploma, but for professional enhancement. Their activities usually focus on general Radiation Protection trends and/or on very specialized topics which cannot be covered by other organizations.

Taking these facts into account, the IRPA E&T Plan is structured around three main lines:

- The cooperation with international and regional organizations dealing with E&T in Radiation Protection;
- The internal E&T activities during IRPA congresses and in the webpage; and
- The stimulation and support of E&T activities organized by the Associate Societies.

— Cooperation with International and Regional Organizations

IRPA is a main stakeholder representing the profession views on E&T needs in radiation protection for both basic levels and continuous professional enhancement. Consequently, IRPA is maintaining cooperation with the International Atomic Energy Agency (IAEA), the European Radiation Protection Training and Education Platform (EUTERP) and the American Academy of Health Physics (AAHP), amongst others.

The IAEA created in 2002 the “Steering Committee on Education and Training in Radiation Protection and Waste Safety” with nominated members representing regional, collaborating training centres, the European Union and professional organizations (IRPA). As observer in the Steering Committee, IRPA is contributing to the implementation of the IAEA Strategic Plan on E&T by exchanging information on actual projects and developments with the AS.

Giving the great opportunity to interact with the main stakeholders on E&T, IRPA is supporting the organization of the ETRAP (International Conference on Education and Training in Radiological Protection) Conference series, organized by the European Nuclear Society. This participation will hopefully continue in the future, after the last one held in 2013 [2].

In the European Union, the EUTERP platform has been created with the main objective of removing obstacles for the mobility of radiation protection experts within the EU through harmonisation of criteria and qualifications for and mutual recognition of such experts. The ENETRAP II project (European Network on Education and Training in Radiological Protection, FP7-EURATOM, 2009-2012) is aimed at the development of European high-quality “reference standards” and good practices for E&T in radiation protection, specifically with respect to the Radiation Protection Expert (RPE) and the Radiation Protection Officer (RPO), see several papers in [2]. These networks could have a clear role to recognize RPE from countries that do not have their own certification system. IRPA has been collaborating in the past with these EU initiatives as observer, and contributed to the development of the definitions of RPE and RPO. The European IRPA AS, which held annual informal meetings, can provide the EU networks with essential feedback from the professional perspective and IRPA can facilitate the establishment of adequate mechanisms.

In the United States of America, the AAHP is an organization that advances the profession of Health Physics, encourages the highest standards of ethics and integrity in the practice of Health Physics, enhances communications among Certified Health Physicists (CHP) and provides a means for Active CHPs to participate in the certification program. The AAHP accredited the training activities (refresher courses and seminars) organized as part of the IRPA international congresses in 2008 (IRPA12, Buenos Aires) and 2102 (IRPA13, Glasgow), and also assigned credits valid for recertification (continuing education programme) to the participants requesting them.

— Education and training activities within IRPA

IRPA has already a long tradition in organizing refresher courses at IRPA congresses. These are lectures by specialists in which updated information on a very precise topic is offered. The E&T Plan looks forward to maintain these activities and to reinforce them by, specifically:

- Including Refresher Courses and Seminars within each IRPA International or Regional Congress (as established in the guidance for IRPA congresses organization);
- Implementing an evaluation and follow-up procedure for the Refresher Courses and Seminars, based on questionnaires to be fulfilled by the participants;
- Improving the post-congress accessibility at the IRPA website to texts and presentations from the Refresher Courses and Seminars (including those from IRPA Regional Congresses).

All IRPA Regional and International congresses integrate an Associate Societies' forum to discuss on the current topics under development and to exchange experiences. E&T is regularly scheduled to be one subject for discussion. These discussion meetings on E&T activities are the way to exchange experiences, promote harmonization and encourage the organization of common and new E&T activities, as well as to stimulate an active participation in the actions proposed in the IRPA E&T Plan.

Finally, the IRPA website has a specific section dedicated to E&T. It contains a presentation of the IRPA E&T Plan, the IRPA definition of RPE, as well as some reference documents. A repository of all the training material presented at the IRPA International Congresses is also kept. A new web-based database has been recently developed to improve access to future or past E&T resources is the. This database will allow to provide a better dissemination of announcements of training courses or activities as well as sharing documents, presentations and training material in general. It includes an easy-to-use searching tool.

— Support to education and training actions organized by the Associate Societies

IRPA AS frequently organize specific training events, such as seminars, short courses and summer (or winter) schools on specialized topics. These activities are somehow unconnected and there is an intention in the E&T Plan to promote good coordination. First of all, a survey is being conducted to have a complete picture of these AS activities. Then, IRPA sponsoring could be granted to those events, which clearly and openly look for professional enhancement within the IRPA family.

The IRPA E&T Plan also considers other actions aiming to stimulate E&T activities at different levels, like the following:

Promote the creation of "E&T networks" which may have dedicated spaces in the IRPA website. For instance, by those societies sharing language (like the Latin-American societies together with Spain and Portugal) or belonging to the same region (for example, the European Radiation Protection Young Scientists Exchange Network, with pilot projects for schools and universities with participation from ÖVS, FS, SFRP, NVS, NSRP and SRP).

Encourage AS activities at national or regional scale to attract young generations to the profession: examples are emerging in some countries to engage pre-university and undergraduate students. Awards programmes to individual or collective work in schools or universities could be an effective way.

Attract young professionals to IRPA Congresses by initiatives like the Awards for young professionals or scientists at every IRPA Regional and International Congress (which have been successfully introduced in the recent years).

CONCLUSIONS

Professional RP associations can significantly contribute to continuous education of their members. Their integration into IRPA can help them to maintain and increase interaction with other associations, in order to share views and experiences and to cooperate in E&T activities. IRPA is also linked with international and regional organizations dealing with E&T in Radiation Protection. The IRPA E&T Plan 2008-2020 aims to stimulate and support AS to organize coordinated activities, to share E&T resources with contributions to the IRPA database on E&T events and resources, to create E&T networks sharing language or regional proximity, and to organize activities to integrate young professionals and scientists in the new IRPA young professionals network. All these actions are intended to foster RP culture through continuous education and training, which is in essence the main role to play by professional societies.

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LEARNING FROM EXPERIENCE AND SHARING LESSONS LEARNED – THE ROLE OF NETWORKS

C. Lefaure

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Abstract

The main purpose of the second generation of networks dealing with radiological protection, which has appeared in the 90's and later, is "learning from experience and sharing lessons learned". They all allow to set up a real community of professionals working" on the spot", regularly communicating through regular meetings, as well as e-mails, web, video conferences or even sharing the web international-data-bases…The example of the French RPO's/RPE's regional networks is a good demonstration of that role of networks in providing in service training mainly supported by voluntaries.

THE SECOND GENERATION OF RADIOLOGICAL PROTECTION NETWORKS' FOCUS

Since the Second World War two generations of networks dealing with radiological protection were born (see [1]). The first one, which gathers national scientific health physics societies, appeared in the 50's and 60's; it was mainly dealing with scientific aspects of radiation protection and technical measurements evolution. These national networks led to the setting up of worldwide associations such as IRPA. The second generation has appeared since the 90's. It is mainly dealing with practical exchanges of experience for the dose management. It involves all types of stakeholders concerned with (occupational) radiological risk management at regional levels (both, international and local). Its emergence has been favoured by the evolution of new standards, as well as socio-political and technological evolutions2 in the 90's.

For that second generation, one can mention here the International System on Occupational Exposure, ISOE, which was set up in 1991, and the European ALARA Network (EAN), which appeared in 1996. After these two first, many others were set up such as ARAN, RECAN, REPROLAM, EMAN, EAN NORM, ERPAN, HERCA, and EUTERP. All these networks are totally devoted to feedback experience exchanges within a sector (nuclear, medical…) or a region (Europe, Asia, Latin America…), in order to improve the radiological protection practices at workstations or for patients. We can say that the main purpose of all these networks is "learning from experience and sharing lessons learned".

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[2] From the standards point of view, the concept of ALARA and how to implement it, were developed. From a socio-political point of view, it was the increase of the so-called stakeholders demand in participating in many collective and individual decisions processes when dealing in particular with the risks' management. From the technological point of view that period has seen the emergence and wide diffusion of totally new communication means such as web and emails.

They all organize regular meetings where professionals from the spot (*not only health physicists, but also specialists of other risks management, managers, labour physicians*,) physically meet to exchange their information among:

- Experience and practices;
- Their problems to be solved *during an operation, in designing a job, a workshop, a new installation, dismantling, feedback, etc.*
- The solutions found and their comparisons; and
- The impact of new regulations on their practices etc.

They all allow to set up a real community [2] of professionals working "on the spot", regularly communicating in between the annual meetings through modern means such as e-mails, web, video conferences or even sharing on the web international data bases. They are a key element in elaborating a common ALARA culture, among all types of stakeholders within utilities and medical services. Some of them even organize specific workshops on training (EUTERP, eventually in cooperation with EAN in 2014 [3]), or provide specific feedback experience analysis on incidents and make it available on the web as tools for trainings (RELIR and OTHEA). They all provide recommendations covering all the previous mentioned topics and addressed to all types of concerned stakeholders: regulatory bodies, managers, trainers for radiological protection, workers, and contractor.

Finally, one can say that the participation in a network life may become officially recognized as part of the "certification" for some stakeholders, as it will be illustrated.

THE EXAMPLE OF THE FRENCH RPO/RPE REGIONAL NETWORKS

Ten years ago in France, many RPO felt isolated, with little legitimacy in the front of their hierarchy and colleagues, they needed exchanges of experiences and updating of knowledge. Some voluntaries started then to set up regional networks. They were 3 of them in 2008, with 300 members; they are 15 in 2014 with 1900 members and they cover the French territory. All of them are inter-sectors (medical, research and non-nuclear industry). A national coordination has been set up in 2011.

Each network organizes 2 one-day workshops per year in its region. During these days regulatory body representatives provide their analysis of regulation evolution and share lessons learned from their inspections. Specialists present epidemiological studies and other technical studies. The most important are presentations by participants regarding their problems and discussions of solutions. These days give also opportunities for exercises of dose assessment and practicing dose rate or contamination measurements in "real" situations with specialists. Last but not least, these networks are now the main providers of the new incident cases and analysis for the RELIR OTHEA system. An agreement was signed in 2013 between the coordination and RELIR. All these actions can be considered as in service training provided by voluntaries and specialists in the networks to other voluntaries. Even if very "young", this has already been recognized by the regulatory bodies, who have shown their willingness that this "in service training" should become part of the renewal of the RPO certification. Therefore, the new French regulation on RPO's training has been modified according to that willingness. In the future any French RPO/ROE regional network will then become partner of certified training organisations. A convention will have to be signed to clarify the quality of the training and allowing verification of the knowledge acquired. This is a good example of the role of networks in learning from experience and sharing lessons learned.

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[3] SHAW P. et al., European ALARA Newsletter 35, October 2014.

RAPPORTEUR SUMMARY OF CONTRIBUTED PAPERS TOPICAL SESSION 11

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INTRODUCTION

Session 11 received 9 contributed papers, which describe the achievements, gaps and challenges in "Education and training in occupational radiation protection". They were presented by 7 countries from Africa, Asia- Europe, Europe and Latin America. The details of the nine contributed paper are shown in Table 1.

TABLE 1. THE OVERVIEW OF PAPERS PRESENTED

No	Title	First Name	Last Name	Nomination	Paper number	Name of the Paper
1	Mr	Zakaria	Yameogo	Burkina Faso	263	Building Competence of Radiation Protection Officers in Industries using Gauging Systems: Case of Burkina Faso
2	Mr	Celal Tugrul	Zeyrek	Turkey	127	The Syllabus On Fundamental Radiation Protection Courses For Radiologists In Turkey, (2011-2013)
3	Mr	Albinas	Mastauskas	Lithuania	226	Education and Training in Occupational Radiation Protection in Lithuania
4	Ms	Camila	Lima	Brazil	154	Cargo Scan: Improving Education and Training in Occupational Radiation Protection of Brazilian Workers
5	Mr	Eduardo Medina	Gironzini	Peru	165	Training in Radiation Protection for Workers Occupationally Exposed in Peru

No	Title	First Name	Last Name	Nomination	Paper number	Name of the Paper
6	Mr	Paulo Roberto	Ferreira	Brazil	151	Methodology for Developing a National Strategy for Education and Training in Occupational Radiation Protection: Overview of Brazilian Actual Status and Planning to Meet the Training Needs of Professionals
7	Mr	Vasileios	Spyropoulos	Greece	296	25 years Education and Training in occupational Radiation Protection and Hospital Safety in the Biomedical Engineering Department of TEI of Athens: Experiences and Perspectives
8	Ms	Sylviane	Prevot	France	175	EST-RAD: A Regional Network of Professionals Dedicated to the Optimization of Occupational Radiation Protection
9	Mr	Luiz Ernesto	Matta	Brazil	300	Reprolam Network Sharing Knowledge and Lessons Learned in Latin America

Africa:

Burkina Faso; Paper: 263

“Building competence of Radiation protection officers in an industry using gauging systems: case of Burkina Faso”, Zakaria YAMEOGO, Delwendé NABAYAOGO,
National Radiation Protection and Nuclear Safety Authority (ARSN), Ouagadougou.

The National Radiation Protection and Nuclear Safety Authority (ARSN) in Burkina Faso has established a legislative framework for protecting people and the environment against radiation risks. It is implemented an annual programme of training of Radiation protection officers to meet the compliance of the law 032-2012/AN on nuclear safety and security and safeguards, and to build competence in radiation protection and the safe use of radioactive sources.

The actual radioactive sources in Burkina Faso are:

- One irradiator with four category I sources of Cs-137;
- More than 46 nuclear gauges of category II, III and IV; and
- a new LINAC irradiator of research is ready to use.
- The future radioactive sources in Burkina Faso will be:
- Two category I sources of Co-60 (555TBq) are expected to be delivered in November 2014; and
- Two radiotherapy services including LINAC and Brachytherapy are currently in the process of construction.

An educational and training framework of Radiation protection officers is established by ARSN to fill the lack of national infrastructure of protection and nuclear safety training.

Asia-Europe:

Turkey, Paper number: 127

“The syllabus on fundamental radiation protection courses for radiologists in Turkey, (2011-2013)”, C. T. ZEYREK, H. AKBIYIK, Ankara Nuclear Research and Training Center, Turkish Atomic Energy Authority, TR-06100, Beşevler, Ankara

The aim of this paper was to describe the Turkish experience in radiation protection (RP) and communicate this experience into RP training courses for radiologists.

The courses provided theoretical and practical knowledge on RP on the basis of scientific and technical recommendations from The International Commission on Radiological Protection (ICRP), The Council Directive 97/43/EURATOM and the International Atomic Energy Agency (IAEA). These courses were organized by the Ankara Nuclear Research and Training Centre (ANAEM) of the Turkish Atomic Energy Agency. The courses were presented as five-day seminars by a group of instructors composed of a physicist, radiation biologists, RP experts, and medical physicists. An overview of the ANAEM syllabus for radiological protection courses was presented along with the percentage of total course time devoted to each module in the course syllabus. The modules with the highest percentage are “On-the job-training for dose reduction” and “Dose reduction techniques for interventional radiologists”.

Similar training programs can be organized for cardiologists and other medical practitioners conducting interventional procedures in institutions and organizations, in accordance with the Turkish RP regulations. The RP training courses have not been accredited at the national level.

Europe:

France, Paper: 175

“EST-RAD: a regional network of professionals dedicated to the optimisation of occupational radiation protection”, Sylviane Prevot, Department of Nuclear Medicine;

Centre G.F. Leclerc, Dijon;

EST-RAD network was founded in 2013 as a non-profit association for radiation protection to provide this area with a multi-sector structure of specific concerns.

EST-RAD aims at keeping professional knowledge up-to-date by:

- Disseminating information and sharing experiences as well as
- Promoting radiation protection
- Developing a multidisciplinary team approach to prevent incidents.

In less than one year, the number of participants has grown to 60 individual members from various sectors – medicine, industry, research, and professional education (80 % work in the medical field) - all of them willing to share their experiences for the benefit of their institutions.

The educational activities consist of two annual continuing education sessions.

Europe:

Greece, Paper 296

"25 years Education and Training in occupational Radiation Protection and Hospital Safety in the Biomedical Engineering Department of TEI of Athens: Experiences and Perspectives", Departmental Standards, Quality, Experimentation and Patent-searching

Prof. Dr.rer.nat. Basile Spyropoulos, Technological Educational Institute (TEI) of Athens, Biomedical Engineering (BME) Department, Athens

This paper dealt with the accumulated experience in training of BME-graduating students of the BME Department of TEI of Athens, in the fields of occupational Radiation Protection (RP) and Hospital Safety (HS). The educational approach has begun with a "virtual walk" around the Hospital Departments, focusing on RP-issues and other HS-technical-managerial Standards, as well as, medical-managerial Guidelines and Protocols. In addition to Lectures and digital Demos, hands-on Practicals related to RP-HS have been offered. More training was available during the compulsory six-month on-the-job training in the BME-Department, in Hospitals, R&D Facilities and Companies. Further, numerous students have been involved, during preparation of their theses, in experimental routine or R&D projects, concerning Dosimetry, Quality Assurance, Acceptance testing, periodic Quality Control (QC) measurements, documentation and other additional advanced RP-HS monitoring of Locations, Patients and Staff.

Europe:

Lithuania, Paper: 226

"Education and Training in Occupational Radiation Protection in Lithuania", Albinas Mastauskas, Ieva Gatelyte, Radiation Protection Centre, Vilnius.

Lithuania has created a radiation protection training system based on the Lithuanian and EU legislations and the IAEA recommendations. Radiation Protection Centre (RPC) is a regulatory authority in charge of implementing the Radiation Protection Training (RPT) system in

Lithuania. On 22 November 2011 it has adopted the Order of the Minister of Health (No. 1001) and has established compulsory radiation protection training and instruction procedure. Personnel responsible for radiation protection at their working facilities, have to be trained by the introductory training programmes before they start to work. They have to be retrained every five years by the refresher training programmes to renew their knowledge.

The RPC is interested in the acknowledgment of occupational radiation protection programs in Universities, which could ensure the proper level of knowledge of graduated persons.

Latin America:

Brazil, Paper: 151

"Methodology for developing a national strategy for education and training in occupational radiation protection: overview of Brazilian actual status and planning to meet the training needs of professionals", Paulo Roberto Rocha Ferreira, Aucyone Augusto da Silva, Institute of Radiation Protection and Dosimetry, Rio de Janeiro,

The Institute of Radiation Protection and Dosimetry (IRD) provides regular education and training courses and co-operates with the IAEA in education and training activities for Latin American and Caribbean countries through various Projects of the Latin American Region – IAEA RLA: 9/066, 9/070 and 9/075. This paper identifies radiation practices in Brazil with the numbers of radioprotection supervisors, the graphics for Brazilian states and regions and the need for radiation protection supervisors for each practice.

The final analysis will contribute to developing an integrated national strategy in the area of education and training in radiation protection.

Latin America:

Brazil, Paper: 154

"Cargo Scan: Improving Education and Training in Occupational Radiation Protection of Brazilian Workers", Camila A. M. Lima, A. R. Lima, Maxim Industrial, Rio de Janeiro.

Brazil has a large territory that borders with almost every country in South America. For more than a decade, the non-invasive inspection cargo systems, has been used worldwide to find illegal products, such as weapons, narcotics, explosives, contraband and even human trafficking through the image of large objects inside cargo containers, unoccupied vehicles, trains, trucks or ships. This technology uses conventional low X-ray generators and linear electron accelerators with high energy between 1.5 and 9 MeV. The linear accelerators must be submitted to a regulatory licensing process and only radiation workers, having radiation protection training, can operate them in Brazil. There are 26 non-invasive inspection equipment in operation in Brazil and a large number of equipment is still being licensed and commissioned. As these non-invasive inspection systems work 24 hours a day, 7 days a week, 365 days a year, it is necessary to have a large number of well-trained radiation workers, mainly in radiation protection to operate the systems, according to the Brazilian legislation. This paper deals with the methodology used to train the radiation workers, using the classroom learning and e-learning, making a total of 140 hours course taught by an Industrial Radiation Protection Officer accredited by the Regulatory Authority. 1200 professionals received radiation protection training in 5 year time by Maxim Industrial, which amounted 98% through classroom training. The geographical distribution of the trained professionals shows that they are from the major urban centres of the country where the ports are located.

There is a need of well-trained professionals, especially in the interior of the country. The use of distance learning technology (e-learning) can provide greater geographic accessibility, allowing empower, improve and enhance the knowledge of professionals from the distant locations and preparing them for the job market.

Latin America:

Brazil, Paper: 300

"REPROLAM Network. Sharing Knowledge and Lessons Learned in Latin America"

Luiz Ernesto Santos De Carvalho Matta, Ana Maria Macchiorlato, Maikol Salas Ramirez, Juan Carlos Hermida Lamanna, Tony Benavente Alvarado.

At the first International Conference on Occupational Radiation Protection: Protecting Workers against Exposure to Ionizing Radiation, which took place in Geneva, Switzerland in August 2012, Action 7 of the Action Plan has specified: To provide a focal point for exchange of information through networking. So the IAEA and ILO, in order to satisfy Action 7, have created and maintained the site ORPNET and encouraged the creation of regional networks for optimizing occupational radiation protection. Several regional networks were created, such as RECAN, ARAN, REPROLAM (Red de Optimización de Protección Radiológica Ocupacional en Latinoamérica). In accordance with the Action Plan for Occupational Radiation Protection of the IAEA, Latin America created its own network to interchange experience and information in the area of occupational radiation protection. Since 2011, many actions have been developed with the intention to strengthen the structure of the organization and to disseminate very useful information in Spanish and Portuguese about topics of interest. It is necessary to promote the participation of all countries of the region, and to have more participating experts and the end users of radiation sources.

Latin America:

Peru, Paper: 165

"Training in Radiation Protection for workers occupationally exposed in Peru", Medina Gironzini, Eduardo, Instituto Peruano de Energía Nuclear.

The Peruvian current regulations require that workers must have an authorization (Individual License), which is granted by the Technical Office of the National Authority of the Peruvian Institute of Nuclear Energy (IPEN), responsible for the control of ionizing radiation in the country. Most of the teachers are professionals who at least have graduated in radiation protection and demonstrated an extensive experience. Since 1972, the Superior Centre of Nuclear Studies (CSEN) of IPEN has conducted various training courses to enable people to work safely with ionizing radiation in medicine, industry and research. Until 2013 it has organized 2231 courses, which resulted in training 26213 people.

CONCLUSIONS

Most of the papers submitted describe own experience and improvement in the acknowledgment and accreditation process in training in the area of radiation protection. Another issue that was raised is the role of networks in keeping radiation protection knowledge up-to-dated, in information disseminated and experiences shared. The impact of the IAEA Projects for developing the Latin America Network, REPROLAM, was demonstrated. Finally, the IAEA Regional Projects have been identified as playing a significant contribution in developing a national strategy in the area of education and training in radiation protection in Latin America. These outcomes serve as an important motivation for further work, which is necessary to ensure appropriate planning to meet the needs of trained professionals in radiation protection.

CHAIRS' SUMMARY OF TOPICAL SESSION 11

OVERALL CONCLUSIONS

- The significant contribution of the IAEA Regional Projects in developing a National Strategy in education and training in radiation protection was acknowledged. The development of national programmes on E&T (needs analysis, design, development and implementation, evaluation of the programme) and building up Regional Training Centres (same language, same problems) should be further encouraged.
- The acknowledgment and accreditation of training in radiation protection is a challenge to be achieved in many countries. The IAEA should continue to provide guidance.
- Better regulation of E&T requirements in RP as well as accreditation of courses/training events/training centres on a national level is necessary in many countries to have a sustainable high-quality programme (graded approach). The IAEA should continue to provide guidance.
- Upgrade of high level courses to master courses, was appropriate.
- E&T, as well as continuous professional development (CPD) in RP is important for the development of RP culture.
- National and international professional RP associations can contribute to E&T improvement by supporting/organizing RP training events.
- The valuable role of Networks in keeping radiation protection knowledge and experience up-to-dated was emphasized and should be further supported by the IAEA.
- Creation of RP networks on a local/national/regional basis: "learning from experience and sharing lessons learned" by professionals is a very valuable development and should be encouraged.
- Further work is still necessary to ensure appropriate planning to meet the needs of trained professionals in radiation protection.

ORAL PRESENTATIONS – SUMMARY

THE STATUS OF AVAILABLE RADIATION PROTECTION TRAINING THROUGH THE IAEA AND THE SUPPORT IAEA PROVIDES TO MEMBER STATES: DEVELOPING AN EDUCATION AND TRAINING STRATEGY FOR THE COUNTRY

(Andrea Luciani, John Wheatley)

The 'Strategic Approach to Education and Training in Radiation, Transport and Waste Safety, 2011-2020', provides inspiring principles for IAEA's education and training activities in the area. Its ultimate vision for Member States is to develop a national strategy for education and training, considered to consist of four interlinked phases: analysis of the needs; design of; development and implementation of; and evaluation of the national education and training programme. For that purpose, the IAEA' Division of Radiation, Transport and Waste Safety is developing guidance for Member States in establishing a national strategy for education and training in radiation, transport and waste safety and is developing and disseminating education and training material. Monitoring mechanisms have been established to evaluate Member States' status and achievements in the field.

NUCLEAR REGULATORY AUTHORITY – 30 YEARS BUILDING COMPETENCIES IN RADIOLOGICAL PROTECTION IN LATIN AMERICA

(Lucía Valentino and Nicolas Rubén)

This paper aimed at emphasizing the work done by the Nuclear Regulatory Authority (NRA) to build competencies in the area of Radiological Protection and Nuclear Safety and explained the process to turn Postgraduate Courses into Specialization Careers of the Buenos Aires University. The benefits for the Argentinian demand and to other Latin American and Caribbean countries due to the higher academic degrees were pointed out.

Achievements and challenges in radiation protection education and training: Tanzania's perspective

(W.E. Muhogora, S. Yusuph, S.L.C. Mdoe and A. Muhulo)

The provision of radiation protection training program is governed by the Atomic Energy Act 2003 and Atomic Energy (Protection from Ionizing Radiation) regulations, 2004. Since 1980s, the country has been striving to improve the radiation protection education and training program using internal and external resources. Despite some notable achievements, major challenges still exist. These include limitations in regulatory requirements, limited certification/accreditation, limited structuring of programmes, as well as inadequate physical and human capacity, and inadequate preservation of nuclear knowledge. Considering desirable characteristics of education and training program in radiation protection and its current status, it can be concluded that the situation needs improvements in order to be of adequate quality and sustainability.

THE ROLE OF PROFESSIONAL SOCIETIES IN PROMOTING RADIATION PROTECTION EDUCATION AND TRAINING

(Eduardo Gallego)

Professional RP associations can significantly contribute to continuous education of their members. Their integration into IRPA can help them to maintain and increase interaction with other associations, in order to share views and experiences and to cooperate in E&T activities. IRPA is also linked with international and regional organizations dealing with E&T in Radiation Protection. The IRPA E&T Plan 2008-2020 aims to stimulate and support AS to organize coordinated activities, to share E&T resources with contributions to the IRPA database on E&T events and resources, to create E&T networks sharing language or regional proximity, and to organize activities to integrate young professionals and scientists in the new IRPA young professionals network. All these actions are intended to foster RP culture through continuous education and training, which is, in essence, the main role to be played by professional societies.

LEARNING FROM EXPERIENCE AND SHARING LESSONS LEARNED: THE ROLE OF NETWORKS

(Christian Lefaure)

The main purpose of the second generation of networks dealing with radiological protection, which has appeared in the 90's and later, is "learning from experience and sharing lessons learned". They all allow to set up a community of professionals working "on the spot", regularly communicating through regular meetings, as well as through e-mails, web, video conferences or even sharing on the web international-database. The example of the French RPO's/RPE's regional networks is a good demonstration of that role of networks in providing in service training mainly supported by voluntaries.

IRPA GUIDING PRINCIPLES ON RADIATION PROTECTION CULTURE DRAWN UP BY RP PROFESSIONALS FOR THE BENEFIT OF RP PROFESSIONALS

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Abstract

The purpose of 'IRPA Guiding Principles for 'Establishing a Radiation Protection Culture' was to capture the opinion and standpoint of radiation protection (RP) professionals on the essential components of a RP culture. The objective was both, to foster a belief in the success of cultural approaches, and to provide guidance to help equip radiation protection professionals to promote a successful RP culture in their organisation and workplace. This document is an overall policy statement that should help RP practitioners in establishing their own practical guidelines and recommendations, commensurate with their own specific issues. This statement has been developed in an inclusive and consultative approach involving all the stakeholders, but should be owned at the highest management level in organizations. Developing a "field culture", in addition to the science, engineering or medical culture, is the way to anticipate problems and to obtain the commitment of all employees. Radiation protection culture is a learned way of life.

INTRODUCTION

— An on-going process

This document is the result of collective and participative work which started years ago, back at the 2008 IRPA Congress in Buenos Aires, where, on behalf of the French Associate Society, we suggested that IRPA addresses this topic in a publication. It was the result of our observation that the French nuclear industry was going through a generation change as and when the use of ionising radiation in the medical field was about to reach a new record high. The issues were different, however radiation protection culture was – and still is - the same. Four IRPA workshops were organised in Europe, Asia and United States, and subsequently a team of representatives was appointed to draw up our guidelines. The Glasgow Congress was another opportunity to organise a session and collect opinions before we could finalise the initial draft. Each Associate Society then had a chance to react and respond to the 3 successive drafts that were posted on IRPA website.

DEFINITION AND OBJECTIVES OF THE RADIATION PROTECTION CULTURE

Embedding RP at a cultural level within an organization is by far the most effective way of delivering the performance to which we all aspire, in order to:

- Give visibility to the fundamentals of RP (science and values);
- Promote radiation risk awareness;
- Promote shared responsibility among practitioners, operators, management and regulators;
- Maintain the RP heritage;
- Facilitate its transmission; and
- Improve the quality and effectiveness of RP.

There are several possible development stages of radiation protection culture. The objective of any culture development program is to move the organizational and individual behaviours towards the highest stage. Strong leadership, education and training, establishment of a positive behaviour at the working place and proper communication among all practitioners have a definite impact on radiation protection culture. Similarly, learning from events, incidents and near misses is an important part of culture development.

Culture can be considered as a system of endurance of knowledge and expertise, with the continuity through education and transfer to the next generation. It is also a combination of conservation and innovation accepted by the group. Based on the IRPA discussions and approved definitions of various types of culture at large in our society, the principal contributions to culture come from three sources:

- Beliefs, values, and assumptions of the founders of an organization;
- Learning experience of group members as the organization evolves; and
- Beliefs, values, and assumptions brought in by new members and leaders.

Organizational culture is therefore a pattern of basic assumptions invented, discovered or developed by a group who have shared significant problems, solved them, and observed the effects of their solutions.

Because there are no differences between sectors (medical, nuclear, industry), whereby radiation protection culture can be understood as a combination of habits and knowledge of RP in all its aspects for workers, patients, population and the environment, and in all exposure situations, combining scientific and social dimensions.

A combination of optimal tools is required to assess the level and quality of radiation protection culture, not only to measure the identified criteria of success, but also to stimulate judgments and observations about positive or negative trends.

ROLES OF PROFESSIONALS

RP professionals within an organization must take the central role in supporting management to drive and embed radiation protection culture throughout the organization. Developing a "field culture", in addition to the science, engineering or medical culture, is the way to anticipate problems and to obtain the commitment of all employees. The RP culture program must impact on all practitioners who can affect workplace exposure, including RP experts, directors and senior managers, middle level managers and supervisors, the workforce (including contractors), those professionals who work with radiation and, where appropriate, designers and suppliers of equipment. IRPA can only reach this wide audience by working through the RP practitioners and the Associate Societies (AS) – i.e. our members. The RP professionals have to achieve the most difficult roles of leadership–, namely that of indirect leadership of their non-RP colleagues, who in many cases may be the business leaders or managers.

A RP professional should identify the main stakeholders who need to be involved in the improvement of the program. Key stakeholders, who should be considered (depending on context and workplace) include:

- The workforce (at all levels);
- Senior managers and Directors;
- Contractors;
- Equipment manufacturers, vendors and suppliers;
- Regulators and other authorities;
- Medical and health professionals, especially but not exclusively those who are using ionizing radiation;
- Functional leaders and risk managers; and
- Patients.

RADIATION PROTECTION CULTURE ASSESSMENT

There are at least four ways to impact radiation protection culture:

- Strong leadership focusing on operational radiation protection culture, and modeling, reinforcing and coaching safety behaviors;
- Educating and training the people involved in RP applications;
- Creating positive and total awareness about RP at working places;
- Establishing adequate and proper communication processes among all the practitioners involved in RP applications.

The assessment tools of radiation protection culture can be done in several ways, using a combination of quantitative and qualitative tools, so as to not only measure the identified criteria of success, but also to stimulate judgments and observations about positive or negative trends, or even to modify them with a view to determining trends and improvements or negative drifts in radiation protection culture. By considering the areas of use of RP and the ways of impacting radiation protection culture as described above, a list of different tools can be identified as the correct and proper tools to measure and assess the degree of success in establishing and developing radiation protection culture.

NEXT STEPS

RP professionals within an organization must take the central role in supporting management to drive and embed radiation protection culture throughout the organization. The development of radiation protection culture must take its place alongside other aspects of safety culture relevant to that organization. Since there is a common basis across all safety culture aspects, there should be a good intrinsic alignment. Where existing safety or radiation protection culture improvement programs are taking place, the RP professional should seek to ensure that they adequately embrace the RP aspects identified in this guide.

The IRPA Congress in Kuala Lumpur in May 2014 gave us an opportunity to organize a special IOMP-WHO session focused on roles and responsibilities of healthcare providers in the area of radiation protection, where the publication of the latest BSS on Radiation Protection in medicine is applicable. The use of ionizing radiation in health care is by far the largest contributor to the radiation exposure of the general population from artificial sources. Safety and quality in the use of radiation in medicine aims to reduce unnecessary radiation risks while maximising the benefit. It is also important to emphasize the need to come up with a radiation safety culture in health care, the education and training needs of RP in medicine and on the role each and every health care provider should play, be they health physicists, physicians or manufacturers. IRPA took advantage of this IOMP-WHO session during the Asian IRPA Congress to think about a new step, new cooperation between IOMP, WHO and IRPA for joint production of a new guiding principle focused specifically on the safety culture in the medical sector.

CONCLUSIONS

Following the process as developed in these Guiding Principles, all persons involved in working with radiation can be directed towards an improved operational focus and, more specifically, to an enhanced engagement on reliability, human performance and organizational effectiveness. This will lead to the development of a “field culture” in addition to the “science, engineering or medical culture”, to anticipate problems and to obtain the commitment of all employees. Radiation protection culture is a learned way of life. There must be an ongoing dialogue among safety professionals, organizational management and the workforce, and between the organization and all relevant stakeholders. Managers and radiation protection professionals play a key role through their presence in the field to coach workers and focus on the operational radiation protection culture.

DEVELOPMENTS IN SAFETY CULTURE — VIEWS BY THE WORLD NUCLEAR ASSOCIATION AND THE INTERNATIONAL SYSTEM OF OCCUPATIONAL EXPOSURE

W. Harris

CHP, NRRPT, Exelon Nuclear, United States of America

Abstract

The International Radiation Protection Agency published the document "Radiation Protection Safety Culture" In addition, the Institute of Nuclear Power Operations has published several documents on improving safety culture at Nuclear Power Plants. Safety culture is a generic and broad term, that has been come to nuclear, radiological and industrial safety culture. This paper will discuss several actions that have been taken at United States Nuclear Power plants to improve safety culture. In addition, the use of the International System on Occupational Exposure and the impact on safety culture will be discussed.

INTRODUCTION

Several recent documents have been published regarding the development of radiation protection safety culture. This paper will primarily focus on the developments and actions that are being implemented in the Exelon Nuclear fleet, but these actions are applicable to all the US nuclear power plants and the plants that are with the World Nuclear Association (WNA).

The WNA is an international organization representing the global nuclear industry, looking to promote a wider understanding of nuclear energy. The WNA has members from all aspects of the nuclear power plant fuel cycle, including uranium mining, the vendors associated with the nuclear fuel cycle, and the operators of the nuclear power plants. There are currently 180 members in the WNA that spans the entire globe. The Radiation Protection working group is a part of the WNA established core areas.

Specifically, the radiation protection working group was founded in 2002. The primary focus is to promote improvements in the international system of radiation protection. The working group is currently focusing on the several actions and initiatives. Recently the working group started reviewing actions in the area safety culture and improvements in ethics.

As stated earlier, the paper will focus on actions being taking in Exelon Nuclear to improve and maintain safety culture. Exelon Nuclear owes 23 nuclear power plants and 14 sites and is the largest operator of nuclear power plants in the United States. Many of the actions taken at Exelon are applicable to all these sites within the fleet and the nuclear industry in general.

Within the United States, the development of strong radiation safety culture is a subset of a strong nuclear safety culture. The actions taken to improve safety culture will improve radiation protection safety culture as well. Actions being taken in the United States include strong leadership, education and training, behaviours, communications, and learning from operating experience. This paper will focus on several of these aspects.

DEVELOPMENTS IN SAFETY CULTURE

The Institute of Nuclear Power Operation (INPO) published a document for nuclear operators titled "Traits of a Healthy Nuclear Safety Culture". This document used by the United States nuclear operators contains very similar concepts as the document "Radiation Protection Safety Culture" published by IRPA. The table below shows the key principles and traits for a healthy safety culture for which the following will be discussed in the paper:

- Everyone is personally responsible for safety
- leaders demonstrate a commitment to safety
- questioning attitude is cultivated, and organizational learning.

TABLE 1. KEY PRINCIPLES AND TRAITS FOR SAFETY CULTURE

Principle	Trait
Everyone is personally responsible for safety	Personal Accountability
Leaders Demonstrate a commitment to Safety	Leader Safety Values and Actions
Trust Permeates the Organization	Effective Communication Respectful Environment Environment for Raising Concerns
Decision Making Reflects Safety First	Decision Making
Nuclear is recognized as Special and Unique	Work Processes
Questioning Attitude is Cultivated	Questioning Attitude
Organizational Learning is Embraced	Continuous Learning Problem Identification and Resolution
Safety Undergoes Constant Examination	Continuous Learning Problem Identification and Resolution

— Leadership

Leaders must demonstrate that they have a commitment to safety in their decisions and behaviours on a day-to-day basis. Leaders have one of the biggest roles in improving safety culture in our nuclear facilities. Leaders have to be seen in the plant, observing, coaching, and reinforcing standards and expectations. Ensuring that leaders are out in the field is one of the key areas that we focus on in the US and at Exelon Nuclear.

A tool used to assist leaders to perform impactful observations is the field observation cards. These observation cards provide the observer key behaviours and traits to observe in the field and serve as a method to document the observations. The observation cards are then collected and on a periodic basis, the observations are analysed to look for trends and develop additional actions as needed.

A key expectation in the field is that leaders correct any poor behaviours observed when they occur. This requires the leader to interface with the workers, provide direct feedback to the worker, and ensure the correct behaviour is understood. If the leader fails to do this condones the poor behaviours and results in less than excellent standards.

— Individual behaviours.

All individuals need to take responsibility for safety. An effective tool to assist in developing this culture is peer-to-peer coaching. This program's established for workers to peer coach each other. For example, this occurs is when a worker actively coaches his other fellow worker to improve their performance. Recognizing a supervisor can't be everywhere, effective use of peer to peer coaching can be as effective as a supervisor coaching a worker.

Significant improvements have been made using this tool in safety culture and in the area of industrial safety. The following chart shows a significant improvement in industrial safety from the uranium mining in Saskatchewan, Canada using tools similar to this. This is just one example of where improvements have been made in safety culture.

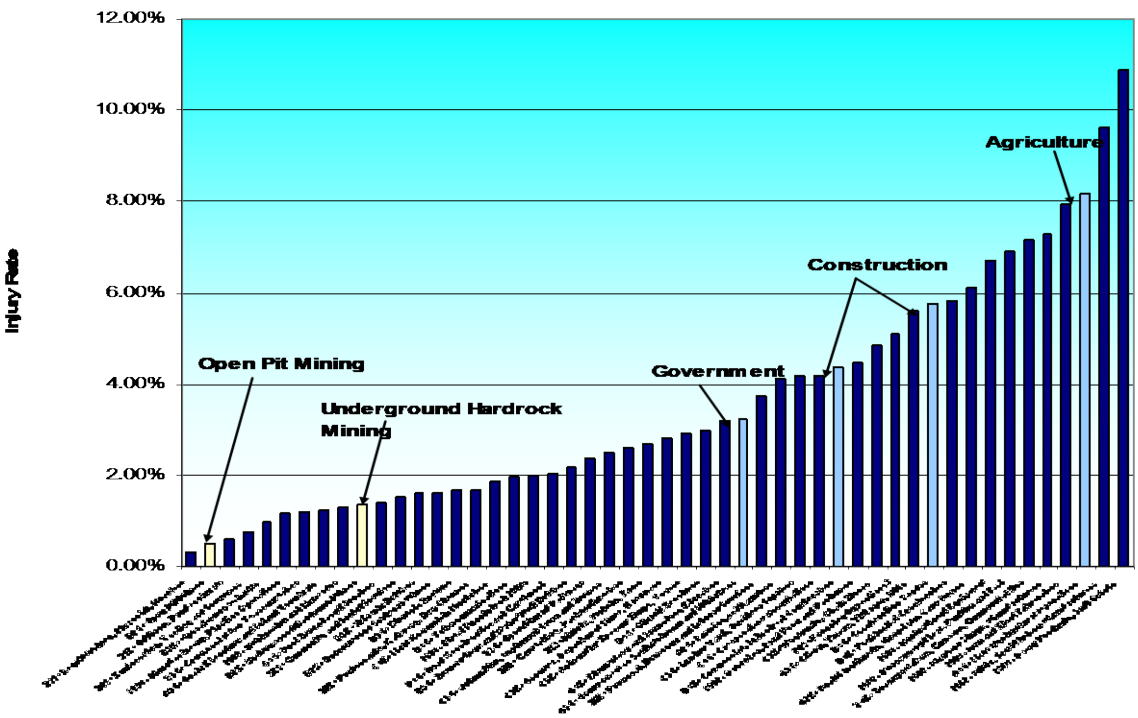

Fig. 1 An example on improvement in industrial safety in uranium mining

— Communication.

Communications will always be needed to maintain a focus on the importance of safety culture. Leaders must always have to be vigilant in how you speak with your co-workers and be vigilant in communications when events occur. One of the tools we've implemented in the US is what we call Human Performance Stoplights. This tool is used to rapidly communicate station events. They're extremely visible at all of our front entrances to the facility and changes based upon events at the station. The colour of the stoplight will be green when there have been no events in the past 24 hours. When an event occurs at a station, the colour is changed based upon the significance of the event to either red or yellow. This simple, but effective tool provides a visual indication to the workers of an event and that additional communications on the event is forthcoming.

— Organizational learning

Issues potentially impacting safety are promptly identified, fully evaluated, and addressed in the corrected action the program. One key element of this is benchmarking. Specific to radiation protection, the International System on Occupational Exposure (ISOE) provides a valuable source of information in this area. Two key things to highlight from the ISOE are the symposiums and the benchmarking trips that are conducted through the ISOE. A key area in the symposium is a discussion of operational events such that learning is from other issues and by not making the mistake yourself.

The ISOE has sponsored several benchmarking trips. There have been several benchmarking trips between the US and Sweden, Sweden and France, France and the US. In addition, the

ISOE sponsored ALARA symposiums are an excellent area for sharing lessons learned. The key below shows significant improvement in occupational radiation exposure as a result of actions discussed above.

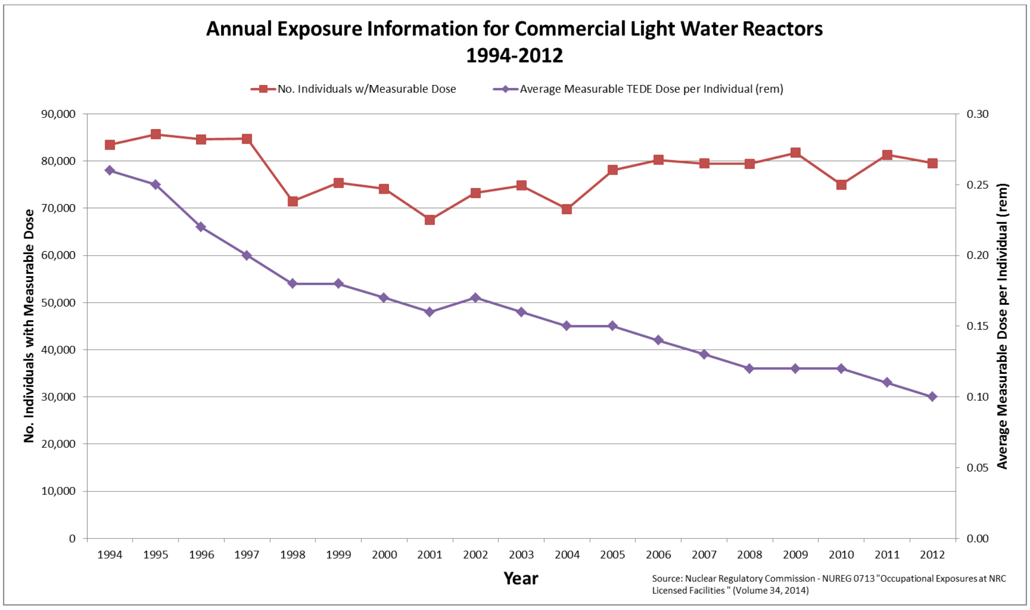

Fig. 2 Improvement in occupational radiation exposure as a result of the actions taken

CONCLUSIONS

Radiation safety culture is a subset of the overall safety culture at a facility. Operators in the nuclear fuel cycle, from mining to nuclear power plants, have taken deliberate actions to improve the safety culture. This has resulted in significant improvements in radiation exposure, industrial safety and reduce events at these facilities.

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CHAIRS’ SUMMARY OF TOPICAL SESSION 12

INTRODUCTION

The subject of session 12 – safety culture – has been mentioned in many of the previous sessions, showing its importance in the context of radiation protection. The three speakers of the session 12 provided a deeper insight as to how establish and maintain a good safety culture. Safety culture is certainly not a concept you can implement in an organization and then forget about it - it's something that needs to be lived in and, as the name implies, needs to be cultivated so that it becomes part of people's daily routine.

Mr. Bernard le Guen, IRPA executive officer, presented the document ‘IRPA Guiding Principles for Establishing a Radiation Protection Culture’. The purpose of this document was to capture the opinion and standpoint of radiation protection (RP) professionals on the essential components of a RP culture. The objective was both, to foster a belief in the success of cultural approaches, and to provide guidance to help equip radiation protection professionals to promote a successful RP culture in their organization and workplace.

Mr. Willie Harris, director of radiation protection at Exelon Nuclear in the United States presented developments in safety culture from the perspective of the nuclear industry with a focus on the work of the Institute of Nuclear Power Operations (INPO) on Safety Culture and the achievements of the International System on Occupational Exposure (ISOE), which was established in 1989 by NEAs Committee on Radiation Protection and Public Health (CRPPH) with the aim to establish procedures for interplant comparability and promote international exchanges on optimization of radiological protection.

Ms. A. M. Bomben from the Autoridad Regulatoria Nuclear in Argentina presented the document 'Safety Culture in organizations, facilities and activities with sources of ionizing radiation' developed by FORO which is a cooperative forum for the Ibero-American Radiological and Nuclear Regulatory Authorities created in 1997. The FORO document on Safety Culture, in its various chapters, develops from the theoretical bases of the safety culture to the practical tools for assessing the level of safety culture in medical, industrial and research activities and also for radioactive waste management and transport of radioactive material. The FORO document also describes indicators of safety culture and proposes ways to promote and develop a strong safety culture. Various topics such as the analysis of the impact of safety culture on the occurrence of radiological accidents and best practices to foster and develop safety culture are addressed in the appendices and annexes.

CONCLUSIONS

- Safety Culture is an ongoing process and a learned way of life.
- Radiation Protection Culture is contained in more general concept of Safety Culture and should be seen as the implementation of RP principles inside the framework of Safety Culture.
- Safety Culture is not established at the same level in the different sectors i.e. nuclear and medical.
- The IRPA Guiding Principles, as well as the FORO project publication, are very helpful tools for any country or organization establishing or improving safety culture.

ROUND TABLE SESSION 1: HEALTH RISK MANAGEMENT

Chairperson: R. Czarwinski, Germany

HEALTH SURVEILLANCE FOR WORKERS OCCUPATIONALLY EXPOSED TO RADIATION — ETHICAL AND TECHNICAL GUIDING PRINCIPLES

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Abstract

Although impressive progress has been made worldwide in occupational radiation protection, the health and safety among workers occupationally exposed to ionizing radiation at large continue to be a concern and allow no complacency and relaxation of vigilance. A well established health surveillance system for workers occupationally exposed to ionizing radiation can assist in minimising the risks at the workplace and in promoting and maintaining workers' health. However, health data are of a sensitive nature. Inappropriate or inaccurate collection of health information can have serious and long-lasting consequences for individual workers. Using the definition of occupational health adopted by the joint ILOAVHO Committee on Occupational Health in 1995 as a starting point, the ILO Technical and Ethical Guidelines for Workers' Health Surveillance provide a good framework for organization of workers' health surveillance. This paper highlights the essential principles on practical aspects of organizing, implementing and managing workers' health surveillance schemes and on collecting, processing, communicating and using health- related data.

Medical examination of workers is an important part of health surveillance, which is one of the functions of occupational safety and health services and should be carried out according to the general principles of occupational health. Such principles are embodied in the ILO's Occupational Safety and Health Convention, 1981 (No. 155), Occupational Health Services Convention, 1985 (No. 161) and their Recommendations, WHO Guidance and ICOH (International Commission of Occupational Health) International Code of Ethics for Occupational Health Professionals.

In 1950, the Joint ILO/WHO Committee on Occupational Health has defined the aims of occupational health as "the promotion and maintenance of the highest degree of physical, mental and social well-being of workers in all occupations, the prevention amongst workers of departure from health caused by their working conditions, the protection of workers in their employment from risks resulting from factors adverse to health, the placing and maintenance of the worker in an occupational environment adapted to his physiological and psychological capabilities and, to summarize: the adaptation of work to man and of each man to his job".

In 1995, the same Joint Committee reviewed this definition and added that "The main focus in occupational health dwells on three different objectives: (1) the maintenance and promotion of workers' health and working capacities; (2) the improvement of working environment and work to become conducive to safety and health; and (3) development of work organizations and working cultures in the direction which supports health and safety at work and in doing so, it also promotes positive social climate and smooth operation and may enhance productivity of the undertaking". Based on the above fundamental objectives and principles, medical examinations of fitness for employment should aim primarily at seeking a balance between the man and his work in order to provide better protection with less strain on the individual.

Medical examinations of workers may be conducted (ILO Recommendation 171):

1) Before assignment to specific tasks which may involve a potential danger to the worker's own health or that of others;
2) At periodic intervals during employment which involves exposure to a particular hazard to health;
3) On resumption of work after a prolonged absence for health reasons for the purpose of determining its possible occupational causes, of recommending appropriate action to protect the workers and of determining the worker's suitability for the job and the needs for reassignment and rehabilitation;
4) On and after the termination of assignments involving hazards which might cause or contribute to future health impairment.

The main purposes of these medical examinations are:

1) To inform the workers of the diseases and contraindications by which they may be affected and to advise them where they can get help in the treatment or correction of their condition;

2) To draw the attention of young persons to their physical and mental aptitudes in order to facilitate correct vocational guidance;

3) To help employers to ensure a wise and rational distribution of workers in the various occupations in industrial undertakings, taking into account not only their technical qualifications but also their physical and mental aptitudes;

4) To avoid the entry into employment of persons who, by reasons of their state of health, would constitute a permanent risk of infection or accident to their fellow workers;

5) To prevent the total exclusion of any worker from employment and to provide for the employment of each worker, in spite of his contraindications, in work which he is capable of performing, taking into account the employment opportunities in the undertaking;

6) To look for the first symptoms of occupational diseases in workers who are exposed to them, i.e., to stop the progress of these diseases at the early stage when they are generally still easily curable, and consequently to increase the chance of curing the victims in the shortest time and before their aptitude for employment is lessened.

Medical examinations should not be carried out as a perfunctory routine. Medical examinations and tests should be governed by a set of principles which include:

1) Selecting appropriate tests which are acceptable to workers;

2) Discarding tests that cannot meet requirement with respect to their relevance, specificity and sensitivity; and

3) Periodically reviewing health surveillance programmes as a whole and modifying them in the light of improved working conditions.

There should be no single form of pre-employment medical examinations. Such examinations should be adapted to the type of work, vocational fitness criteria and workplace hazards. When conducting a medical examination, the following general guiding principles should be kept in mind:

1) Health assessment by questionnaire may suffice for most jobs;

2) There should be no discrimination against disabled or handicapped applicants who meet the requirements of a given job.

3) The health assessment should be conducted bearing in mind the possibility of improving the working conditions through ergonomic engineering, the innovative design of work process and the elimination of occupational hazardous agents, or through replacement or substitution of these with safer methods.

It is important to emphasize that medical examinations should be used to improve working conditions in such a way that will facilitate the adaptation of work to workers and under no circumstances should medical examinations for employment be used as a substitute for measures to prevent and control hazardous exposures.

The use of biological monitoring tests, which are simple and have the best validated action levels, are particularly useful in workers' health surveillance when properly used and are cost-effective when used for individual and collective monitoring of exposed workers. However, they should not be a substitute for the surveillance of the working environment and the assessment of individual exposure. Priority should be given to environmental (exposure limits) over biological (biological exposure limits) criteria.

It is a very complex issue to determine a person as "fit" or "unfit" for work purely on the basis of medical examinations.

Within an occupational health perspective, there is no such thing as fitness for employment in general; it can only be defined in terms of a particular job or type of work. In this context, fitness reflects the relationship between the demands of the job and the abilities of the person who is to do the job. As both the work and the worker's health status are highly subject to change, any assessment of fitness for employment should be open to review since it can be considered as a compromise relating to one point in time.

Similarly, there is no such case as absolute "unfitness" for employment. The dichotomous conception of "fit/unfit" has been an issue of debate in recent years. A concept of a "conditional fitness" has emerged which reflects a shift from a static concept of "unfitness" to a more active one of "adaptation" which emphasises the link between health and employment. Under this concept, a person, after having been examined, will be identified either as "no contraindication found" for the job or "contra-indicated" temporarily or permanently for exposure to a specific working condition, method, procedure, or material, which will allow an appropriate solution including finding an alternative employment to be worked out that may better serve the interest of the person concerned and avoid the unnecessary exclusion.

When a diseased or physically handicapped person is examined for fitness for employment, two major risks should be avoided: the first is to overestimate functional disability by failing to allow for any adaptation of the job to the worker, while the second is to underestimate an intelligent and determined person's ability to overcome his disability and produce satisfactory results in a job that might appear beyond his powers. Fitness for employment has to be tested in close relation to ergonomics and functional and vocational rehabilitation.

Prevention of misuse of the results of medical examination for fitness and avoidance of discrimination of the worker examined are a major concern of the ILO. The ILO Occupational Health Services Convention and Recommendations (1985) laid down general principles which should govern the occupational health practice, including the manner in which occupational health services should be established and operated, and detailed guiding principles on worker's health surveillance in general and on fitness test for employment in particular.

The general principles include in particular that:

1) A comprehensive national policy on occupational health should be formulated in consultation with the most representative organizations of employers and workers;
2) Medical examination should be free to the workers;
3) The employer, the workers and their representatives, where they exist, should co-operate and participate in the implementation of the organisational and other measures relating to occupational health services on an equitable base and in decisions affecting the organization and operation of these services.
4) Medical examinations should be conducted by qualified occupational personnel or other health care professionals designated by the national competent authorities.

The guiding principles on workers' health surveillance and fitness including the follows:

1) The privacy of the workers should be protected and it should be prevented to use medical examinations for discriminatory purposes or in any other manner prejudicial to worker's interests;
2) Records of medical examination should be kept in accordance with national regulations. Data of a medical nature should be accessed only by medical professionals;
3) Conclusion of the medical examination for employment should be communicated in writing to both the worker and the employer and these conclusions should contain no information of a medical nature;
4) If a worker in a particular job is found medically contra-indicated, every effort should be made in finding him alternative employment or another appropriate solution;
5) The worker to be examined should be fully informed of the health hazards involved in his work, of the results of the medical examination he has undergone and of the assessment of his health;
6) The worker has the right to be advised individually on his health in relation to his work.

Medical examinations should serve for prevention and protection purposes, which cover not only the protection and promotion of worker's health, but also the protection of his access to work, entitlement to compensation, health insurance benefits and social protection. In no way, should medical examination for employment be used as a substitute for efforts in improving working conditions and adaptation of work to man and of man to his work.

Furthermore, medical examination should be the last step in the process of recruitment when it is carried out. To minimize the risk of discrimination on the grounds of health selection effect of the medical examinations, the decision of employing a person should have already been made in principle before the person is asked for a medical clearance. A procedure of appeal should exist.

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WHO'S VIEWS ON HEALTH EXAMINATIONS IN DIFFERENT WORKPLACES

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Health is a human right and it is defined in the WHO Constitution as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity". The global workforce represents half the world's population. The health of workers is an essential prerequisite for productivity and economic and social development. Occupational health hazards represent a substantial contribution to the Global Burden of Disease (GBoD). Approximately 2 million annual deaths worldwide are due to work-related diseases: this represents 5500 deaths per day. Workers suffer 270 million occupational accidents and 160 million occupational diseases each year. Further research is still needed to precise the magnitude of this GBoD attributable to occupational exposure to radiation. Workers' health is determined not only by workplace hazards but also by social and individual factors and access to health services. Despite the availability of effective interventions to prevent occupational hazards and to protect and promote health at the workplace, large gaps still exist between and within countries with regard to the health status of workers and their exposure to occupational risks. The growing informal economy is often associated with hazardous working conditions and involves vulnerable groups such as pregnant women and migrant workers. WHO is promoting the implementation of the Global Plan of Action on Workers' Health that deals with all aspects of workers' health, including primary prevention of occupational hazards, protection and promotion of health at work, improvement of employment conditions, and a better response from health systems to workers' health. It is underpinned by certain common principles:

- All workers should be able to enjoy the highest attainable standard of physical and
- mental health and favourable working conditions.
- The workplace should not be detrimental to health and wellbeing.
- Primary prevention of occupational health hazards should be given priority.
- All components of health systems should be involved in an integrated response to the specific health needs of working populations.
- The workplace can also serve as a setting for delivery of other essential public-health interventions, and for health promotion.
- Activities related to workers' health should be planned, implemented and evaluated with a view to reducing inequalities in workers' health within and between countries.
- Workers and employers and their representatives should also participate in such activities.

WHO, supported by its Global Occupational Health Network (GOHNET) of collaborating centres and in partnership with ILO and other intergovernmental and international organizations, is encouraging Member States to implement the Global Plan of Action and to adapt it to their national priorities and specific circumstances in order to achieve the following objectives:

- Objective 1: to devise and implement policy instruments on workers' health;
- Objective 2: to protect and promote health at the workplace;

- Objective 3: to improve the performance of and access to occupational health services;
- Objective 4: to provide and communicate evidence for action and practice; and
- Objective 5: to incorporate workers' health into other policies.

Health examinations at the workplace have to be considered in the context of health promotion, as the process of enabling people to increase control over, and to improve, their health. Improving the health of workers can be achieved through well-coordinated efforts of society as a whole, under government leadership and with substantial participation of workers and employers. Health promotion includes actions to improve individual workers' behaviour as well as a wide range of environmental and social interventions to promote and sustain health e.g. education and training, air quality, water quality, chemical safety and radiation safety. Therefore, health examinations at the workplace in the context of an occupation radiation protection programme should be integrated to the more generic workers' health promotion approach. The development of such a strategy has to consider the different health care dimensions i.e. safety, effectiveness, patient-centeredness, timeliness, efficiency and equality. Occupational health services should be considered in the notion of Universal Health Coverage (UHC) that encompasses population coverage, service coverage and cost coverage.

While "occupational health" surveillance refers to the collection of information about conditions in the workers' health as well as in the working environment (i.e. work hazards and risks), the concept of "workers' health" surveillance refers to the assessment of the health of workers by means of detection and identification of diseases/abnormalities. It may include clinical examination, biological monitoring, health surveys, imaging procedures, reviews of workers' radiation dose records and workers' health records. Radiation protection should be integrated in the occupational health programs and should be considered when designing workers' health surveillance programs.

New emerging scientific evidence about tissue reactions following radiation exposure highlights the need to consider health effects such as circulatory diseases (and visual impairment due to lens opacities/cataracts. Workers at risk of cataract development are particularly those exposed to a relatively uniform whole-body exposure, highly non-uniform radiation exposure in which the head may be particularly exposed, and workers exposed to weakly penetrating radiation (e.g. beta particles, low-energy photons). Regarding radiation-induce cancer risk, taking into account the linear non-threshold approach for the dose-response relationship, all occupationally exposed workers are potentially at risk. The most common scenarios of workers exposure are the medical applications, workers from mines, mineral processing plants, oil, gas and other extractive industries, nuclear industry (NPPS, nuclear fuel cycle), radiation sources used for academic and/or research purposes and, finally, radiation emergencies. Annually worldwide, about 7 million health workers incur radiation doses attributable to their occupation, which represents about 75% of all exposed workers. Health surveillance of these workers has to take into account radiation risks (both tissue reactions and stochastic risks). In general doses are higher in staff involved in fluoroscopy-guided interventional procedures, as well as nuclear medicine staff (e.g. PET/CY, cyclotron) and manual brachytherapy workers. Radon concentration may be very high in enclosed workplaces and it is known that radon represents the second cause of lung cancer after smoking (3-14% of lung cancers could be attributed to radon). Health surveillance programs should consider co-morbidities (e.g. dust inhalation-related pneumoconiosis). Natural Occurring Radioactive Materials (NORM) industries produce 80% of the worldwide annual collective dose from occupational exposures and workers' doses can be substantially high. Exposure scenarios are diverse and may involve different radionuclides (radon, radium, thorium, etc.). In contrast with radon that as is inert gas, radium has affinity for other tissues and therefore, it may result in an increased risk of bone cancer, lymphoma, leukaemia and aplastic anaemia. Health surveillance of emergency workers after a nuclear accident has to consider the risks of acute radiation effects, increased risks of cataract and circulatory disease, thyroid cancer risk after intake of radioactive iodine. Mental health disorders and psychosocial impact are major health consequences of radiation emergencies. Finally, particular considerations for female workers are applicable to all occupational exposure scenarios in terms of workers health promotion and health surveillance (e.g. pregnant female workers, female workers of reproductive capacity, female workers who are breastfeeding in case there is a risk of internal exposure to radionuclides in the workplace).

ETHICAL AND TECHNICAL GUIDING PRINCIPLES ON HEALTH SURVEILLANCE FOR WORKERS OCCUPATIONALLY EXPOSED TO RADIATION — POINT OF VIEW FROM A MINISTRY OF HEALTH

O. Luxenburg

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The Ministry of Health's (MOH) main role is to seek the best health care to ensure the well-being of the population, prevent disease and promote health. The regulator has to decide when to intervene and what tools to use to promote safety issues. The regulator TOOLBOX includes legislation, guidelines, incentives to promote activities, training and more. MOH Health promotion strategy includes three parallel and sequential processes: regulation; implementation assessment with data collection; and health promotion and disease prevention activities.

Regulation is carried out through laws, orders and Director General announcements. However, the complexity arises from the involvement of different regulatory agencies in radiation protection. In Israel, these include the Ministry of Environmental Protection, the Ministry of Health, the Ministry of Economy, the Ministry of Transportation and the Israel Atomic Energy Commission. Thus, the legislation to safeguard workers and to patients in the health institutions rises from diverse sources. The main laws in this field are: "The organization, supervision and surveillance of occupational safety" (2013), "Safety Regulations at Work – Occupational Health and the health of the ionising radiation employees" (1992), "Female Workers Regulations – for women exposed to ionising radiation" (1979). The MOH has published the regulatory requirement:" Protection of the Patient from Ionizing Radiation in Medical Exposure".

Implementation Assessments with Data collection focuses on both, the organizational contribution to health, as well as on the development and areas of the health risk and assessment tools for workers. Workplace Health Promotion Survey is a tool to assess the degree of implementation of best practice interventions in the workplace. The information produced by the continuous data-collection promotes regulatory updates through laws, regulations and directive general announcements.

Health promotion and disease prevention is facilitated by lecturing, medical meeting, research and publications on organizational and individual strategies to prevent and screen for occupational diseases. Inspections of occupational medicine clinics assure the quality of occupational prevention and health care.

Gaps and future planning: In order to assess health and productivity outcomes of workers, it is required to create an occupational disease registry that correlates occupation with recorded illness and injury by periodically collecting employer report and linking this data via patient ID number.

CHAIR'S SUMMARY OF ROUND TABLE 1 – HEALTH RISK MANAGEMENT

Health risk management is a topic particularly relevant for health authorities, regulatory authorities as well as for international organizations and their qualified collaboration. The Roundtable offered a platform for an interesting discussion between representatives from WHO – Maria del Rosario Perez, from ILO – Shengli Niu and from the Israeli Regulatory Authority – Osnat Luxenburg. They stated uniformly that occupational radiation protection has to be part of the general workers' health surveillance and should attain the highest standard of physical and mental workers health. Its integration in the global agenda of occupational health is therefore unavoidable. Nevertheless, priority in the health risk management has the prevention of occupational health hazards.

Key statements as outcome of the discussion are:

- Promotion of health needs an integrated approach
- Incorporation of radiation protection occupational health surveillance into health surveillance of workers – a way forward?
- Cooperation is needed between different regulatory ministries and agencies pertaining to radiation protection

All panellists highlighted the fact that the public is nowadays more interested in health and healthy working conditions and a strategy for the promotion of the health at workplaces should be developed and implemented. Such health promotion strategy includes three parallel as well as sequential processes – regulation, implementation with data collection and health promotion and disease prevention activities. WHO pointed out that there are still existing large gaps between and within countries with regard to the health status of workers and their exposure to occupational risks, which demand a concrete future planning of activities and an integrated approach of regulators and international organizations such as WHO and ILO to overcome these gaps. It was clarified that occupational health surveillance refers to the collection of information about conditions in the workers' health as well as in the working environment; the concept of workers' health surveillance refers to the assessment of the health of workers by means of detection and identification of diseases.

The mission of the key players in the health risk management is to create a multi-dimensional perspective of protecting and safeguarding the individual, taking into account the whole life exposure to radiation and its implication. The issue is complex due to new emerging knowledge on tissue reactions, genetics etc. and its influence over health and the need for a "personalized medicine". A worker has to be considered as one individual as a whole and ways have to be found to combine health record data on the individual from different databases in order to have a "whole picture" regarding the individual's health considering that health data are of sensitive nature. Such data should not only be collected but they should be analyzed for developing and implementing effective prevention measures to avoid occupational hazards.

Radiation health risk assessments as part of the general health risk management should be regularly conducted for all possible exposure scenarios. Because there are still areas, which need further research regarding occupational radiation risks, a strategic research agenda inter alia for epidemiological questions is required.

Risk management strategies should be tailored to each scenario. The responsibility for the implementation of radiation protection laws and regulations in many countries is shared among several government ministries and agencies. The discussion of the presentations clearly indicated that there is a continuing need to foster the collaboration between the different competent authorities and agencies pertaining to radiation protection (e.g. Regulatory Authorities, Health Authorities) and to establish an efficient networking. However, collaboration should not mean doing the work of the others. Therefore, a definition of the different roles is required (formulated by different authorities). The target is a win-win-situation for all key players and for the welfare of the worker/individual. It is crucial to synchronize policy and to work in coordination.

After the national policy for radiation protection is formulated, it is needed to check its implementation in the field and its impact on protecting workers. One of the biggest challenges of the regulator is getting the knowledge to which extend the laws and regulations are implemented in practice. Therefore, it is essential for the regulator to follow-up and gather data on actual implementation and provide feedback to all involved parties to ensure the comprehensive protection of the worker.

The Israeli representative gave a good example for an appropriate way forward: The regulatory authority of Israel establish a forum for all interested parties to discuss issues in risk management for workers e.g., implementation assessment, use of health related data for estimation of the fitness for the job, the role and responsibility of occupational health professionals. The biggest challenge is seen in the question how to combine all information on the individuals.

A further essential element of the discussion concerned the importance of the radiation risk communication. The worker has to be fully enlightened on the radiation risks at the workplace. He also has to be informed on possible alternative employment.

Finally, occupational radiation protection should be part of the health risk management and should be considered when designing workers' health surveillance programs.

ROUND TABLE SESSION 2:

THE APPLICATION AND INTERPRETATION OF INTERNATIONAL STANDARDS IN EMERGENCY PREPAREDNESS AND RESPONSE

Chairperson: W. Weiss, Germany

PROTECTION OF EMERGENCY WORKERS AND HELPERS IN RECENT DEVELOPMENTS IN INTERNATIONAL STANDARDS FOR EMERGENCY PREPAREDNESS AND RESPONSE

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Abstract

The paper discusses the latest developments in the revision of the IAEA Safety Requirements in preparedness and response to a nuclear or radiological emergency with regard to protection of emergency workers and helpers. These Safety Requirements are expected to be published in 2015 as Part 7 of the General Safety Requirements and will supersede the existing Safety Requirements Publication No. GS-R-2 issued in 2002. This paper is based on these revised draft Safety Requirements and discusses the requirements for protection of the following categories: (a) emergency workers who are designated prior to an emergency; (b) emergency workers who cannot be designated prior to an emergency; and (c) helpers (i.e. volunteers from the public). Consideration is given to the respective rights and duties of emergency workers and helpers, as well as to duties, responsibilities and commitments of the employers. This paper also provides an overview of the comprehensive framework for protecting emergency workers and helpers and includes specific requirements related to protecting female emergency workers and to the transition phase.

INTRODUCTION

In its statutory functions, the International Atomic Energy Agency (IAEA) is authorized to establish and adopt "*standards of safety for protection of health and minimization of danger to life and property*" from the harmful effects of ionizing radiation, "*including such standards for labour conditions*". In addition, the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency [1] assigns the IAEA with a responsibility to collect and disseminate to States Parties and Member States information concerning "*methodologies, techniques and available results from research related to nuclear accidents or radiological emergencies*". The IAEA fulfils this function partly through Safety Standards in the area of emergency preparedness and response (EPR). The IAEA Safety Standards in EPR [2-4] illustrate an international consensus on what constitutes an adequate level of preparedness to effectively respond to a nuclear or radiological emergency, including aspects related to the protection of emergency workers.

Since the first Safety Guide on Responding to Radiation Accidents in 1969 [5], all Safety Standards in EPR have been developed in a joint co-sponsorship with the International Labour Organization (ILO) and present a joint work of both international organizations to contribute to the protection of emergency workers.

The Safety Requirements, specifically dedicated to EPR [2], were endorsed in 2002. Building on experience from the responses to actual emergencies, these Safety Requirements set common goals to be achieved and the common approaches to be taken for an adequate preparedness to effectively respond to a nuclear or radiological emergency. In 2011, the revision of this publication was initiated to take into account experience and developments since 2002. Protection of emergency workers has received particular attention in light of lessons identified from the past emergencies, including the Fukushima Daiichi Nuclear Power Plant (NPP) accident. The revision resulted in a strengthened, more comprehensive and harmonized system for protection of emergency workers and helpers as discussed below. It builds upon the work carried out on the matter throughout the development of the IAEA Safety Standards published in 2011 [4,6].

EMERGENCY WORKERS AND HELPERS – RIGHTS AND DUTIES

— Emergency worker: definition, designation, rights and duties

The IAEA Safety Standards [6, 7] define an '*emergency worker*' as "*a person having specific duties as a worker in response to an emergency*". This definition covers the following categories: (a) relevant employees of operating organizations, referred to as licensee and registrants, and (b) relevant personnel from other response organizations and personnel such as response managers, rescuers, firefighters, medical staff, members of monitoring and sampling teams, and drivers and crews of evacuation vehicles. Emergency workers would also include relevant personnel engaged in providing medical support and care to members of the public in an emergency, irrespective of the organization they are coming from, for example the national Red Cross organizations. It is implicit that the definition of '*worker*' includes not only those employed directly by an employer, but also those engaged indirectly, through a contract.

The majority of emergency workers described above will be designated as emergency workers prior to an emergency. However, past experience has shown that the response to an emergency may require involvement of emergency workers who have not been designated prior to the emergency (still being recognised as a 'worker' prior to the emergency) or even those who were not recognised as 'workers' prior to the emergency, as defined in the IAEA Safety Standards [6]. Based on the experience from the past emergencies, it is important to recognise that there is a broad range of people, who may be responding to an emergency as emergency workers [8,9].

Due to the specific meaning of the term '*worker*' in the IAEA Safety Standards [6], which is included in the definition of '*emergency worker*', the latter definition implies that: (a) emergency workers have rights and duties related to occupational radiation protection, and (b) their employer (e.g. an off-site response organization or an operating organization) has responsibilities, commitments and duties towards the emergency worker in relation to his/her assignment in EPR. These rights, responsibilities, duties and commitments of both, emergency workers and their employers relate to those elaborated in the IAEA Safety Standards in EPR [2-4,7].

However, if emergency workers have not been designated prior to the emergency, the discharge of these rights and duties, as well as the discharge of their employer's responsibilities and duties during an emergency will be challenged particularly with regard to: the voluntary basis of emergency workers for performing specific emergency tasks, obtaining worker's consent, ensuring that emergency worker is aware of expected duties and responsibilities and the way how they will be carried out. In depth discussion on these issues throughout the process of development of the new IAEA Safety Requirements in EPR [7] resulted in additional clarification of the definition of emergency workers and the relevant requirements:

(a) Adequate importance is given to the designation of emergency workers prior to an emergency and this involvement is not recognized as such prior to the emergency;
(b) Emergency workers, irrespective of their designation prior to the emergency, clearly understand their duties and responsibilities and they are provided with opportunities to be trained on them;
(c) Workers employed, both directly and indirectly, by the response organizations are recognized as emergency workers;
(d) Employers understand their responsibilities, commitments and duties in occupational radiation protection, so these can be effectively discharged in the emergency response; and
(e) Awareness raises the possibility to integrate emergency workers, who have not been so recognized prior to the emergency, into the response organization during the emergency.

— Helpers in an emergency: definition, rights and duties

In the aftermath of the Fukushima Daiichi NPP accident, members of the public volunteered to perform emergency response activities [10]. This revealed that voluntary contribution by members of the public in an emergency response cannot be excluded. Thus, the revised Safety Requirements in EPR [7] address these volunteers as "*helpers in an emergency*". Helpers are "*members of the public who willingly and voluntarily help in response to a nuclear or radiological emergency" although they "are aware that they may be exposed to radiation*".

This has provided a basis for giving helpers the right to be protected in accordance with their duties and responsibilities [7]. Requirements have been set on how helpers will be integrated into the emergency response organization and how they will be afforded an adequate level of protection. Being members of the public, helpers do not have an employer. Therefore, arrangements to protect helpers in an emergency requires an identification and designation of an organization to be assigned with responsibilities, commitments and duties for integrating helpers into an emergency.

FRAMEWORK FOR THE PROTECTION OF EMERGENCY WORKERS AND HELPERS IN AN EMERGENCY

— Overall considerations

The framework for protecting emergency workers and helpers in an emergency is described in the revised IAEA Safety Requirements in EPR [7]. While some elements of this framework have been part of the IAEA Safety Standards [2, 11] earlier, some elements address the latest developments in these standards. It is understood that such a framework should be a part of the respective emergency plans. Arrangements encompassed in the framework are to be subject to regular testing in exercises. The feedback obtained from these exercises should update the framework. Adequate qualifications of emergency workers and their training on a regular basis should not be underestimated in the overall emergency arrangements.

a) Assessing hazardous conditions in which emergency work might be undertaken

The first step in affording an adequate level of protection to emergency workers is the identification of the anticipated hazardous conditions, both on and off the site, in which emergency workers may have to perform their duties. Employers have the responsibility to do so in accordance with the IAEA Safety Requirements in EPR [2, 7]. The employers need to consider the details of the emergency tasks to be carried out, as well as the personal protective and monitoring equipment. The overall goal to be achieved is preventing emergency workers from incurring radiation exposures or other impacts that can result in severe health hazard [12]. Meeting this goal requires comprehensive preparations at the preparatory stage, for example: designating emergency workers for specific emergency tasks; identifying for which tasks emergency workers may be subject to exposures exceeding occupational dose limits and other hazardous conditions; identifying to whom employers need to provide comprehensive information on the risk involved; identifying the training needs and needs for personal protective and monitoring equipment.

b) Assessing the fitness for duty of emergency workers

As for any worker occupationally exposed to ionizing radiation, emergency workers must be fit for their intended duties during an emergency [7]. Designating emergency workers prior to an emergency and assessing the hazardous conditions in which they might perform their duties provides an assurance to employers that the fitness of emergency workers for their expected duties is adequate. Such an evaluation requires a system to provide health surveillance: [6, 7].

c) Managing doses received and communicating health risks to emergency workers

The IAEA Safety Fundamentals [13] recognize the possibility for emergency workers to receive doses exceeding "occupational dose limits normally applied – but only up to a predetermined level." The IAEA Safety Standards [2, 6, 7, 11] have recognized these specific situations, but requires that emergency workers be protected as in planned exposure situation. Where this cannot be done, employers must ensure that emergency workers are volunteers, that they are clearly and comprehensively informed about the associated health risks and protective measures and that they are adequately trained for these emergency conditions. Specific situations may include: life-saving actions, actions preventing severe deterministic effects, actions preventing the development of catastrophic conditions that could significantly affect people and the environment, and actions averting a large collective dose.

In relation to such tasks, existing IAEA Safety Standards [4, 6] provide guidance values for restricting further exposures to emergency workers under the assumption that doses due to weakly penetrating radiation and from skin contamination are prevented. However, past experience, has shown that doses due to external penetrating radiation may not provide a sufficient measure of the overall hazard for emergency workers [12]. The revised IAEA Safety Requirements [7] require that as early as possible after an emergency response, the total effective dose and the weighted absorbed dose to an organ or tissue are to be estimated and further exposures restricted as appropriate. The revised IAEA Safety Requirements in EPR [7] provide guidance values for restricting further exposures to emergency workers as shown in Table 1.

TABLE I. GUIDANCE VALUES FOR RESTRICTING EXPOSURE OF EMERGENCY WORKERS [7]

<table>
<tr><td rowspan="2">TASKS</td><td colspan="3">GUIDANCE VALUES</td></tr>
<tr><td>$H_p(10)$</td><td>E</td><td>AD_T</td></tr>
<tr><td rowspan="2">Life saving actions</td><td>< 500 mSv</td><td>< 500 mSv</td><td>$< \frac{1}{2}AD_T$, SDE [a]</td></tr>
<tr><td colspan="3">This value may be exceeded — with due consideration of the generic criteria used for taking actions to prevent severe deterministic effects to occur [4, 6, 7] — under circumstances in which the expected benefits to others clearly outweigh the emergency worker's own health risks, and the emergency worker volunteers to take the action and understands and accepts these health risks</td></tr>
<tr><td>Actions to prevent severe deterministic effects and actions to prevent the development of catastrophic conditions that could significantly affect people and the environment</td><td>< 500 mSv</td><td>< 500 mSv</td><td>$< \frac{1}{2}AD_T$, SDE</td></tr>
<tr><td>Actions to avert a large collective dose</td><td>< 100 mSv</td><td>< 100 mSv</td><td>$< \frac{1}{10}AD_T$, SDE</td></tr>
</table>

[a] Values of the RBE weighted absorbed dose to an organ or tissue, at which protective actions are to be taken in an emergency have been designed so that severe deterministic effects are avoided or minimized [4, 6, 7].

Dose management for emergency workers requires a comprehensive system for monitoring and controlling doses so that the use of individual dosimeters is possible. Such a system must also include the possibility to register all emergency workers and the doses incurred; continuously monitor hazardous conditions in which emergency workers are to perform their tasks; plan the expected emergency work while accounting for the hazardous conditions; assess the total effective dose and weighted doses to an organ or tissue via all exposure pathways; and communicate to emergency workers the doses received.

d) Provision of medical support

The revised IAEA Safety Requirements in EPR [7] provide a basis for a common approach towards providing a medical support to emergency workers and helpers. This includes generic criteria in terms of received dose consistent with criteria for members of the public (effective dose of 100 mSv in a month) at which medical actions need to be taken (e.g. screening, longer term medical follow-up and counselling) to detect early and to effectively treat radiation inducted health effects. Should emergency workers approach or exceed the thresholds for severe deterministic effects, they must be provided with an immediate examination, consultation and medical treatment as indicated. As seen in the past [9], irrespective of the doses received, emergency workers need to have the right to be given psychological counselling and continuous medical care during the emergency response and their employer shall commit to do so.

e) Further occupational exposure following an emergency response

Following the emergency, the major issue that may arise among emergency workers, who may have non-emergency jobs involving occupational exposure, is how to account for the exposures incurred during an emergency in relation to the occupational dose limits. Exposure incurred during emergencies has led to limitations and restrictions in the day-to-day work of these workers. This issue has been addressed by the IAEA Safety Standards [2, 6, 7, 11], which require that "*emergency workers who receive doses in a response to a nuclear or radiological emergency shall not be normally precluded from incurring further occupational exposure*". Any decision to restrict further occupational exposures following an emergency response needs to be based on a qualified medical advice for the intended duty [6, 7]. Such a qualified medical advice needs to be obtained if an emergency worker has received an effective dose exceeding 200 mSv or at the request of the emergency worker and before any further occupational exposure.

— Specific considerations for emergency workers not designated in advance and for helpers

During an emergency response, emergency workers who cannot be designated prior to the emergency and helpers need to be provided with the same level of protection as designated emergency workers considering their assigned duties. However, as they cannot be identified prior to an emergency, they would need to be registered prior to undertaking emergency tasks and to be integrated into the overall emergency response organization. They must be provided, before they assume their specified duties, with 'just-in-time' training. Such training will include instructions on: actions to be taken under emergency conditions, health risks, protective measures available and how these measures are to be applied. Provision of such instructions will provide a basis for obtaining a consent to take tasks listed in Table 1. Due to the fact that emergency workers not designated in advance and helpers will have only limited relevant training and experience (if any), the revised IAEA Safety Requirements [7] requires that helpers be subject to dose limits for occupational exposure in planned exposure situations, while emergency workers not designated prior to an emergency shall not to be selected for life-saving actions. Doses received by helpers needs to be managed as required for emergency workers.

— Specific considerations for female emergency workers

The IAEA Safety Standards [2,4,6,7,11] do not limit the involvement of female emergency workers in an emergency response. In this context, protection of female emergency workers needs to account for the possibility of severe deterministic effects to the foetus from all exposure pathways of greater than 100 mSv [7, 14,15]. Consequently, female workers, who are aware that they are pregnant or might be pregnant, need to notify their employer. The employer has the responsibility to inform the female worker of the associated health risks to the foetus.

Should such female volunteer in taking tasks listed in Table 1, the employer needs to ensure that such tasks will not result in an equivalent dose to the embryo or foetus exceeding 50 mSv [7]. Therefore, employers must make adequate arrangements for assessing and monitoring the conditions in which female emergency worker may need to do tasks ensure that adequate protective equipment is provided to her and that she is trained in its use, and assess the equivalent dose to the embryo and foetus following the emergency work.

— Specific consideration for the transition phase

The revised IAEA Safety Requirements in EPR [7] account for different approaches in protecting emergency workers during the urgent and early phases of an emergency and during the transition from the emergency to the existing exposure. Actions in the transition phase can be taken after detailed planning. This provides the opportunity for a more stringent protection of emergency workers by following the occupational radiation protection requirements for planned exposure situations. However, it has to be recognized that for the duration of the transition phase there may be areas where emergency workers may still be subject to the guidance values as listed in Table 1. Moreover, involvement of helpers is most expected during this phase. Therefore, adequate arrangements to protect emergency workers and helpers need to consider not only the urgent and early phases, but also the transition phase. Further work on these issues is ongoing and will be addressed in the future Safety Guide [16].

CONCLUSIONS

Ensuring protection of emergency workers and helpers in a nuclear or radiological emergency requires full commitment by employers, as well as emergency workers and helpers. The system ensuring protection of workers and helpers needs to build upon existing occupational radiation protection measures, but also needs to take into account the specifics of an emergency situation.

The revised IAEA Safety Standards in EPR [7] comprehensively cover the overall arrangements needed to be put in place by the Member States to protect emergency workers and helpers in a nuclear or radiological emergency. Establishment of such a framework and its implementation will contribute to an enhanced occupational radiation protection.

The Safety Guide publication [17] is under development and will provide further guidance and recommendations consistently with the revised safety requirements for emergency preparedness and response [7].

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EMERGENCY DOSE CONTROL FOR WORKERS AT THE FUKUSHIMA DAIICHI NUCLEAR POWER STATION ACCIDENT

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Abstract

In responding to the Fukushima Daiichi NPS accident, the dose limit for emergency workers was temporarily increased to 250mSv from the previous 100mSv. It is necessary to revise the emergency dose limit beforehand, and it should be considered to maintain consistency with the globally recommended level. On-site works after the NPS accident is clearly different from that before the accident. It may be reasonable to introduce a new restriction concept having more flexibility in keeping the same safety level for normal situation.

INTRODUCTION

This document describes the application of emergency dose limit for workers involved in the Fukushima Daiichi NPS (FDNPS) accident. The issue of the current emergency dose limit and consideration of the dose restriction for workers in post-accident stage are also discussed.

APPLICATION OF EMERGENCY DOSE LIMIT AT FDNPS ACCIDENT

The dose limit for emergency workers was 100mSv in Japanese regulation, but in responding to the FNDPS accident, it was difficult to continue in the response work within this dose limit. The dose limit for emergency workers was increased from 100mSv to 250mSv on March. When the emergency dose limit of 250mSv was adopted, the Radiation Council in Japan issued a statement that this change was appropriate in light of consistency with internationally recommended values (500mSv). The emergency dose limit thereafter returned to 100mSv on December 16, 2011 when it was confirmed that the reactors were stabilized and the accident in the station was settled. At this point, the normal dose limit of 100mSv per 5years and 50mSv per year was adopted, except for those who continued to be involved in emergency work that could not have been avoided and who were restricted to the emergency dose limit of 100mSv.

An opinion was conveyed that doses received during emergency work should be treated separately from the normal work dose limit according to the ICRP 2007 recommendations. However, the regulatory authority issued an administrative guidance that doses received during emergency work shall be added to doses received during normal work and the limit of 100mSv per 5years shall be applied.

RESULTING WORKERS DOSES

The distribution of the accumulated individual dose to on-site worker is indicated in Fig.1. [1] In first year after the accident (FY2011), 21,135 workers were engaged in on-site work and the average dose was 12.46mSv. In the subsequent years, FY2012 and FY2013, the average dose was 5.74mSv, 5.25mSv. respectively. These are approximately 5 to10 times higher than before the accident, when the annual average dose was 1.4mSv per year (FY2009). Six workers received, during emergency, a dose that exceeded the emergency dose limit of 250mSv. All these workers were TEPCO employees and they were operators or engineers that were in the main control room observing the progress of the accident on monitoring instruments. They have undergone periodic examinations by physicians and no abnormality in their health status has been detected. 174 workers (including six workers) received over 100mSv in total. They were not allowed to assume any radiation work after the emergency dose limit returned to 100mSv on December 16, 2011.

DISCUSSIONS

— Regarding the future of emergency dose restriction in domestic regulation

Revision of dose restriction to emergency workers is currently under discussion in Japan. The following points should be included into the discussion of dose limit revision: (a) Be consistent with the levels globally recommended by ICRP and IAEA. (b) Establish 'reference levels' (not as dose limit') of doses depending on the degree of the emergency. (c) The doses in an emergency should be treated separately from doses received in normal situation.

— Considering restriction of doses in post-accident stage

The post-accident works after the NPS accident were clearly different from those before the accident. Fig.2 shows a schematic chart of the change in radiological situation. On-site works after NPS accident, The radiation levels after the accident were still high on-site.

The ICRP recommended the implementation of the three types of exposure situations: planned, emergency, and existing. The question was which exposure situation should be applied to on-site workers in the post-accident stage. As described above, the present condition is clearly different from that before the accident. Considering these facts, it may be reasonable to introduce a new restriction concept by establishing a more flexible dose restriction criteria that has the same safety level as dose limitation of normal occupational exposure, such as 200mSv per ten years and 50mSv per year.

CONCLUSIONS

Consistency with the globally recommended levels should be considered when revising the emergency dose limit. In post-accident stage, it may be reasonable to introduce a new restriction concept, which will have more flexibility in the worker's dose restriction.

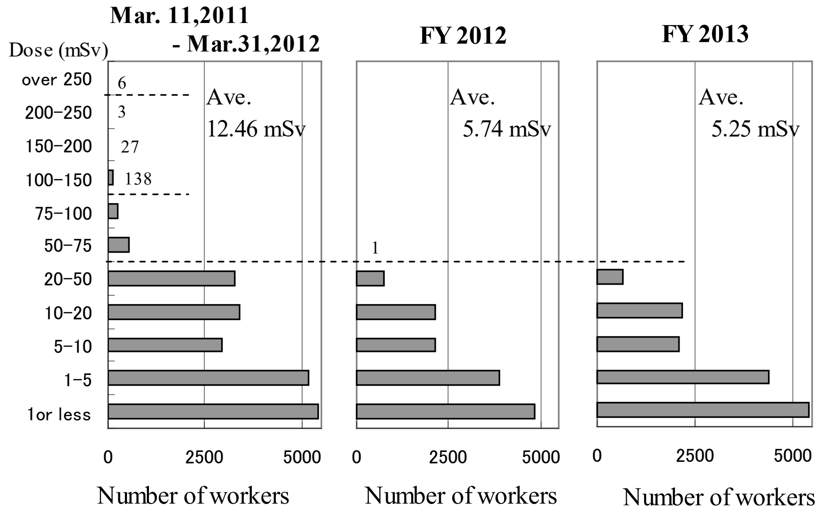
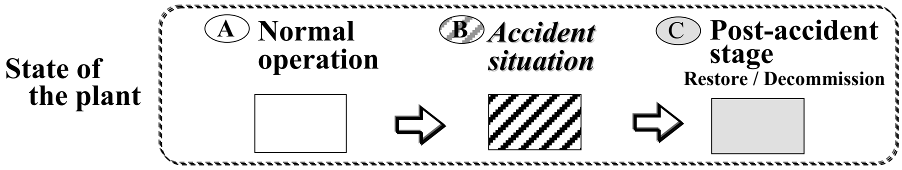


FIG. 1. Individual dose distributions (trend over three years)



Exposure situation		Planned	Emergency	?
Radiation level		**Low**	***High***	***High***
Source control	As whole facility	**Controlled** (well known)	**No**	**Controlled**
	As each sources	**Controlled** (well known)	**No**	***Uncertainty of information of source conditions***
Protective criteria		**Dose limit (normal)**	**Reference level**	**?**

FIG. 2. Change in situation from radiological aspect

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TEMPORARY INCREASE IN THE EMERGENCY EXPOSURE DOSE LIMIT IN RESPONSE TO THE TEPCO FUKUSHIMA DAIICHI NPP ACCIDENT

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INTRODUCTION

In response to the accident at the TEPCO Fukushima Daiichi Nuclear Power Plant, the Japanese government declared a nuclear emergency on 11 March 2011 and implemented emergency operations to prevent the accident's expansion. For prompt implementation of the operation, the Ministry of Health, Labour and Welfare (MHLW) promulgated an exemption ordinance to increase radiation exposure dose limits from 100 mSv to 250 mSv during emergency work at the affected plant. After the settlement of early-stage confusion of the accident, the MHLW had reduced the emergency dose limit back to the original limit step by step. This paper explains the decision-making process and deliberation on temporarily raising the emergency dose limit and the key challenges that require further deliberation to resolve [1,2].

RAISING OF EMERGENCY DOSE LIMITS

The Prime Minister Office demanded to raise the emergency dose limits at the affected plant on 14 March 2011. The limits were set at 100 mSv since 1998. The MHLW did not have any other option but to raise the emergency exposure dose limit because, under the nuclear emergency declaration, appropriate response actions were needed to prevent the expansion of the nuclear disaster. The MHLW decided to employ 250 mSv as the emergency dose limit. Radiation exposure of 250 mSv is the minimum dose that causes chromosome disorders in lymphocyte cells, which are not clearly defined by the onset of clinical symptoms. A radiation dose of 500 mSv causes transient leukopenia with a clinical symptom, and consequently, reduce resistance to infections [3].

The MHLW promulgated an exemption ordinance on the 15 March 2011 and put it into effect from 14 March 2011. The MHLW made it clear that the increased dose limit applies exclusively to the emergency work needed at the affected plant and that this exceptional limit would be returned to 100 mSv once the nuclear emergency is cancelled.

During emergency operation, there was internal controversy within the government over the dose control. The MHLW has required employers that the combined dose of emergency and normal exposure should not exceed the normal exposure dose limit if emergency workers were back in normal radiation works in other NPPs. In response, the Nuclear and Industrial Safety Agency (NISA) asserted to the MHLW that the emergency exposure dose should be distinct from the normal exposure dose. The NISA argued that if the emergency work continued, approximately 320 workers would exceed 100 mSv, and 1,600 workers would exceed 50 mSv. It could result in a shortage of qualified personnel to perform periodic inspection and maintenance at the other NPPs. The MHLW declined the NISA proposal from for the following reasons:

- No sound reasons were provided to distinguish emergency doses from normal doses, even though the health effects from each of them are equal.

- A long-term shortage of personnel would not occur because qualified technicians and engineers in related industries could be trained and tentatively transferred.

The MHLW, however, issued an administrative guidance document on 28 April 2011 allowing ex-emergency workers to exceed the annual dose limit of 50 mSv during normal radiation work in other NPPs, with the consideration that if the combined normal and emergency doses did not exceed the 5-year dose limit of 100 mSv, the health risks due to radiation exposure would remain within the tolerable risk.

REDUCTION OF THE EMERGENCY DOSE LIMITS

The Minister of the MHLW proposed on 29 August 2011 the following to the Minister for Nuclear Accident Settlement:

- As soon as the nuclear reactors are stabilized, the government should terminate the application of the emergency dose limit.
- The government should reduce emergency dose limits even during emergency work, as much as possible to adhere to the principle of optimization.

The ministers agreed to deliberate on the reduction of the emergency dose limit on 15 September 2011:

- Before stabilizing the reactors, the government would reduce emergency dose limits for newcomers from 250 mSv to 100 mSv.
- Following the reactors' stabilization, the government would abolish the exemption ordinance enacting the temporary rise in the emergency dose limit to 250 mSv.
- In both cases, the government shall pay appropriate attention to avoid disturbing the emergency work.

— First Phase of the Dose Limit Reduction

The monthly average exposure doses from March to August 2011 showed a consistent decrease. Thus, at the end of September 2011, the MHLW acknowledged that newcomers' exposure would not exceed 100 mSv even if the maximum exposure dose in August, 18.3 mSv, had continued for six months. However, TEPCO emphasized the possibility that newcomers' exposure may exceed 100 mSv in cases where they were needed to engage in troubleshooting tasks. The MHLW, therefore, decided to apply 250 mSv emergency dose limits exceptionally to newcomers responding to a loss or serious malfunction in a) the cooling systems of the nuclear reactors and b) the confinement and enclosure of radioactive substances, and enforced the amendment of the exemption ordinance on 1 November 2011.

— Second Phase of the Dose Limit Reduction (Abolishment of the Exemption Ordinance)

TEPCO submitted reports to the MHLW in October 2011, which requested the following three points as the condition for terminating the emergency limits of 250 mSv:

- Re-establish an emergency dose limit of 250 mSv when serious problems arise following the completion of the reactors' stabilization.

- Apply an emergency dose limit of 100 mSv during work related to the cooling of nuclear reactor and the confinement of radioactive substances after stabilizing the reactors.
- Provide necessary transitional measures for workers who were exposed to more than 100 mSv.

The MHLW accepted the first and second requests, and, as a response to the third, it proposed transitional measures that would apply the 250 mSv dose limit exclusively to shift supervisors exposed to more than 100 mSv for a few months, to get sufficient time to transfer the knowledge and expertise to new supervisors.

However, TEPCO insisted that a few months was insufficient time to train new operators as shift supervisors. Therefore, the MHLW suggested excluding the inside of the Seismic Isolated Building from the radiation control areas, so those shift supervisors can stay in the building and supervise emergency operations.

With the consent of TEPCO, the MHLW abolished the exemption ordinance on 16 December 2011, when the stability of the reactors was declared. Successively, the MHLW excluded the inside of the building from the radiation control areas, and approximately 50 shift supervisors exposed to more than 100 mSv were able to stay in the building up to the end of April 2012.

DISCUSSIONS

The increase and subsequent reduction in the emergency dose limit was decoded at the political level. To avoid political intervention, the government required a pre-defined protocol for the process and conditions to apply or amend emergency dose limits.

Regarding setting of emergency dose limits, the dose limit of 250 mSv was sufficient to implement the necessary emergency operations in response to the accident with multiple reactors meltdown.

The application of high-level emergency dose limit to all workers without any exception was unavoidable in the early stage of the accident. After the chaotic situations were resolved, the government established plural emergency dose limits and applied them to specific works, based on the urgency of the work and the ambient dose rate at the work site.

CONCLUSIONS

Lessons learned from this experience tell us what the government should do [4]:

- Before the accident, decide on a protocol to set emergency dose limits, such as the post-accident amendment of the limits following the accident situation.
- Establish plural emergency dose limits and apply them to specific works based on the urgency of the work and the ambient dose rate at the worksite.
- Specify conditions to apply to emergency dose limits. The conditions should be clear and objective because the government needs to make a quick decision based on insufficient information.
- As soon as the situations allow, terminate the application of the emergency dose limits using a phased approach, and to this end, designate the conditions and rules at which to

terminate or reduce the limits before the accident such as accumulated and expected exposure dose and,

- Create a procedure for radiation control of workers exposed to more than the 100 mSv as the 5-year dose limit during emergency work to keep lifetime exposure below 1 Sv.

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OCCUPATIONAL RADIOLOGICAL PROTECTION — THE ICRP PERSPECTIVE TAKING INTO ACCOUNT LESSONS FROM THE FUKUSHIMA DAIICHI ACCIDENT

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Abstract

In principle, the regime for protection of workers during an emergency should follow that used during normal planned operations where feasible. However, it is recognized that this is not always possible or sensible, and therefore flexibility is needed. In part this flexibility is seen in the application of reference levels rather than dose limits, and in the understanding that doses incurred may be much higher than during normal operations where circumstances warrant. Learning from experiences of the Fukushima Daiichi accident, several questions are being examined with an eye to updating ICRP recommendations. These include how to manage: the various types of workers in different phases of the emergency and recovery; workers on-site vs. off-site; and, recovery workers who have already received doses greater than 100 mSv during emergency operations.

CURRENT RECOMMENDATIONS

The most recent recommendations of the International Commission on Radiological Protection (ICRP) regarding occupational radiological protection related to emergency preparedness and response can be found in the Commission's 2007 Fundamental Recommendations (Publication 103) [1], and in publications dealing specifically with emergency exposure situations (Publication 109) [2] and recovery after an accident (Publication 111) [3]. Some recommendations in Publication 63 Principles for Intervention for Protection of the Public in a Radiological Emergency [4], as referred to in these later publications, continue to apply.

It is well known that "Response actions should be planned because potential emergency exposure situations can be assessed in advance, to a greater or lesser accuracy depending upon the type of installation or situation being considered." (Publication 103 para 274) "However, because actual emergency exposure situations are inherently unpredictable, the exact nature of necessary protection measures cannot be known in advance but must flexibly evolve to meet actual circumstances. The complexity and variability of these situations give them a unique character" (idem). "Emergency workers and their roles should be identified in advance. Emergency workers may include radiation workers (e.g. employees of registrants and licensees) and people who are not normally occupationally exposed to ionising radiation, such as police, rescue personnel, fire fighters, and medical personnel." (Publication 109 para 12).

> "The exposure of workers responding to an emergency who are implementing an emergency plan can generally be seen as deliberate and controlled, although this is not always the case; thus, some flexibility is required. Therefore, where feasible, the system of radiological protection consistent with that for planned exposure situations should be applied. Nevertheless, there may be a need to take protective actions promptly during an emergency, necessitating exposures for some workers higher than the dose limit for planned exposure situations (such as to help endangered people or to prevent the

exposure of a large number of people). In such cases, it may be acceptable for emergency workers to receive, on the basis of informed consent, doses that exceed the occupational dose limits normally applied. Nevertheless, such doses should be optimised and be below a predetermined dose level appropriate to the type of task undertaken. The predetermined guidance values should take into account the assessment upon which the emergency plan is based, together with expert radiation protection advice." (Publication 109 para 14).

ICRP recommends grouping emergency workers into three categories (Publication 109 para 15):

Category 1: Workers engaged in urgent action at the site of the accident

"Workers in the first category are those who must act to save life, to prevent serious injuries or to prevent a substantial increase in potential doses to members of the public. These people are most likely plant personnel but may also be emergency service workers such as firemen. It is not appropriate to recommend maximum levels of dose for these situations. Emergency interventions usually have a high degree of justification when intervention is aimed at saving human lives or preventing individuals from incurring very large doses beyond the thresholds for deterministic effects. In relation to other goals, the justification must be carefully considered in relation to the expected benefit. It is recommended that every effort should be made to keep doses below those at which serious deterministic health effects may occur, i.e. 1 Sv effective dose or 5 Sv equivalent dose to skin for all actions except life-saving action for which higher doses may be justified." (Publication 63 para A2)

"Workers who may be called upon to undertake those actions should be volunteers. They should be trained in the actions that may be required and they should be informed of the risks of radiation." (ICRP Publication 96 para A3) "[They] should be given adequate protection [their] doses should be monitored and recorded [the] dose received and any possibility of health consequences should be assessed and explained to the worker after the accident. A high dose received in an accident should not necessarily preclude a worker from returning to radiation work." (Publication 63 para A4)

Category 2: Workers implementing early protective actions and taking action to protect the public

With respect to Category 2, the Commission now recommends that protection should be consistent with the full system for planned exposure situations where this is feasible. … The new advice can be thought of as requiring the optimisation of protection below a reference level of dose that is equivalent to the occupational exposure dose limit. (Publication 109 para 16).

Category 3: Workers implementing recovery operations during the intermediate phase

"Workers in the third group should be subject to the normal system of radiological protection for occupational exposure […]" (Publication 63 para A6).

WORK IN PROGRESS

Shortly after the Fukushima Daiichi accident, ICRP formed Task Group 84 on Initial Lessons Learned from the Nuclear Power Plant Accident in Japan vis-à-vis the ICRP System of Radiological Protection. This Task Group reported directly to the Main Commission, and was asked to develop recommendations to inform the programme of work of ICRP. One of the eighteen issues raised by Task Group 84 in their summary report [5] relates directly to occupational radiological protection in emergencies and the follow-up to major events. In particular, this report noted that "The ICRP system of occupational protection is not specifically tailored to workers who are not 'radiation' workers but who nevertheless may be highly exposed to radiation in specific circumstances, a notable example being the 'rescuers' that intervened in the accident. The system was not conceived for people who are willingly taking high risks for saving lives or other charitable endeavour. The system is even less tailored to volunteer workers, namely, casual helpers in an emergency." ICRP Task Group 93, on the update of ICRP *Publications 109* and *111*, is examining many of the lessons being learned from the Fukushima Daiichi accident. Although the system of radiological protection has proved to be robust even in the face of this challenge, there is room for improvement. The work of Task Group 93 is ongoing. At this stage several key issues relating to exposures of responders have been identified: emergency situations are not normal and flexibility is needed; distinctions between responders on and off site, and in different phases, are important; not all responders are equally prepared prior to an emergency; and, all responders need a level of protection appropriate to their work. Significant effort is being directed at a careful examination of the complexities in protection of the various types of workers and the various circumstances in which they find themselves. These include, for example: those such as plant personnel who were already considered radiation workers and have knowledge and training specific to dealing with radiation; emergency responders such as fire fighters, medical personnel, and other rescue workers; off-site recovery workers employed by an authority or private company, volunteers in the recovery effort, and homeowners and business owners working to improve their own properties. In addition, it is clear that there are important differences between protection of personnel on the reactor site and those off-site. The situation may be considered stable with respect to the risk for further major off-site releases, while there is still great uncertainty with respect to conditions on site where workers need to continue to contend with the potential for rapidly evolving conditions and potentially very high dose rates. Furthermore, there is the question of how to handle workers engaged in recovery work who, during emergency operations, have already received doses of more than 100 mSv (the five-year occupational dose limit for planned exposure situations (*Publication 103* Table 6)). As noted above, "a high dose received in an accident should not necessarily preclude a worker from returning to radiation work" (*Publication 63* para A4). A clear recommendation on how this should be managed is needed.

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CHAIR'S SUMMARY OF ROUND TABLE 2

The Application and Interpretation of International Standards in Emergency Preparedness and Response

The aim of the round table discussion was to identify opportunities and challenges in the application and interpretation of international standards for the protection of emergency workers including helpers. Background information was provided by E. Buglova (IAEA) on "Protection of Emergency Workers and Helpers: Recent Developments in International Standards in Emergency Preparedness and Response" as well as on lessons from Japan after the emergency at the Fukushima Daiichi NPP. A. Suzuki, (TEPCO) reported about "Emergency dose control for workers at the Fukushima Daiichi nuclear power station accident" and S. Yasui (Ministry of Health, Labour and Welfare, MHLW, Japan) provided the rationale of the "Temporary Increase in the Emergency Exposure Dose Limit in Response to the TEPCO Fukushima Daiichi NPP Accident". Chr. Clement (ICRP) explained the "ICRP Perspective Taking into Account Lessons from the Fukushima Daiichi Accident - Application and interpretation of international standards in emergency preparedness and response".

Key messages of these presentations are:

- The current and forthcoming IAEA Safety Standards in emergency preparedness and response provide a comprehensive framework for the protection of emergency workers and helpers in a nuclear or radiological emergency. Through clear definitions of *emergency worker*, *worker* and *helper* these standards clearly identify and allocate, among other issues, the duties and responsibilities of emergency worker and the responsibilities, commitments and duties of their employers in occupational radiation protection in an emergency. One essential element of this framework specifies guidance values for restricting exposure of emergency workers in exceptional circumstances like life-saving actions as well as the provision that emergency workers who receive doses in an emergency response are not to be precluded from incurring further occupational exposure.
- With the aim to expedite the emergency operations in the Fukushima Daiichi NPP after the accident, MHLW issued an exemption ordinance on 11 March, 2011 to increase the emergency dose *limit* for workers tasked with NPP in-plant operations in unavoidable circumstances from 100 mSv to 250 mSv (effective dose). This level was considered sufficient to implement the necessary emergency operations in response to the Fukushima Daiichi NPP accident. Agreement was achieved at governmental level on September 15, 2011 to reduce the emergency dose limit for "newcomers" from 250 mSv to 100 mSv. Administrative guidance by the regulator specified a maximum acceptable exposure level for workers of 100 mSv over 5 years including the dose by emergency work after the accident.
- The highest worker exposures were observed during the first year after the accident (March 2011 to March 2012) when the exposures of 6 TEPCO worker exceeded 250 mSv - most of the doses were caused by internal exposures; additional 168 workers received doses between 100 mSv – 250 mSv. These 174 emergency workers were not able to engage further in radiation work.
- According to the published recommendations of ICRP (Publications 63, 103, 109) a thorough preparedness including a clear allocation of roles and responsibilities for response are key pre-requisites to achieve the best protection under the circumstances

in an emergency. In response to a nuclear or radiological emergency, the key principles of radiological protection - justification, optimization, and dose limitation - remain valid and have to be applied. A Task Group of ICRP is working on an update of recent recommendations (Publications 109 and 111) based on lessons learned from the Fukushima accident.

The discussions of the presentations clearly indicated that there is a continuing need to further develop and establish a solid basis at national levels for the protection of emergency workers and helpers based on existing safety standards and other international recommendations. This would require an open dialogue between the radiation protection community and external stakeholder, in particular policy and administrative organizations, legal experts and the broad spectrum of available emergency response organization. The professional ambition to achieve the best protection of emergency workers under the circumstances requires thorough and realistic planning during the preparedness stage, which would include major efforts to improve the qualification of the management and the worker. In addition, the qualification has to include training in flexible decision-making, which can be of key importance in complex emergency situations to achieve a good balance between the individual radiation induced health risks of emergency worker and the risks of people in life-threatening situations caused by an emergency which would require urgent life-saving actions.

There is a need to improve the provisions for the protection of helper in emergencies in terms of administrative measures related to the allocation of responsibilities for provisions of information and personal protection, training, dose record keeping, and medical follow up. The forthcoming IAEA safety standards (primarily, GSR Part 7) provide clearly what needs to be achieved in this regard, but it may take some time and efforts before they will be implemented by operational organizations at national level.

Further guidance and better explanation of the existing safety standards is needed on:

- The use of dose *limits* or *reference levels* or *guidance values* (pre-defined and fix or flexible, multiple levels for different workers or for specific work situations?) including further clarification of the various dose levels proposed;
- The *transition* from a planned exposure situation to an emergency exposure situation, as well as from an emergency exposure situation to an existing exposure situation.
- The necessity, if any, for
    - Specific exposure control of workers who are exposed to more than the 100 mSv (5-year dose limit) during emergency work to keep lifetime exposure below 1 Sv or
    - Any work restrictions for further work by highly/over-exposed worker.
- The necessity for special medical follow-up requirements for highly/over-exposed worker (what type of requirements, for which time period?).

Despite the availability of clear recommendations and safety standards at international level (ICRP, IAEA), further efforts are needed to implement these standards and recommendations at national level in the operational world with the aim to ensure that emergency worker and helper, who play a key role in emergency situations, receive the best protection under the circumstances.

ROUND TABLE SESSION 3:

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE – THE WAY FORWARD

Chairperson: R. Padovani, Italy

A TECHNOLOGIST'S PERSPECTIVE

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Scatter radiation from the patient is the biggest source of occupational dose exposure to the radiation technologist and staff. The ICRP has established three principles for an overall system of radiation protection; justification, dose limitation and optimization of protection. He further stated that the size of the exposure for the occupational radiation exposure is directly related to the size of the x-ray field and the beam's intensity [1]. The corner stone for radiation protection and protecting radiologist from the exposure to scatter radiation is to incorporate time, distance and shielding techniques. One might think that in fluoroscopy procedures the highest dose for occupational exposure would be to the hands, but research supports the fact that the highest scatter dose happens below the table. Because the scatter radiation that a radiologist receives is directly related to the size of the x-ray field and the beam intensity, it is also important to decrease patient dose whenever possible. This will in turn also decrease the occupational dose. As an operator you should set up protocols that incorporate the lowest radiation dose possible, while ensuring high image quality. There are several websites that house the latest research on best dose limits. One of the websites that is most accurate and contains latest information is the Image gently website. This website covers all imaging areas in radiology and the information is based on the peer review research. In addition to using the lowest dose possible one can apply radiation protection tools to reduce occupational dose as well. There are three ways to protect radiation workers from radiation exposure, first protection is provided by equipment construction and workspace design, by using the appropriate architectural shielding and equipment mounted shielding. Second, there is personal protective equipment and third the radiologist must understand the type of radiation they are working with and apply the inverse square law.

Radiation protective measures didn't occur until the 1915 when the British Roentgen society adopted a resolution recommending x-ray tubes needed to be shielded with lead to protect the worker. Before this time there weren't any regulations that protected the worker and there is extensive documentation about people that died or had radiation burns before they knew how to shield the equipment. The NCRP issued their first recommended maximum exposures in 1934, report 116.

Chronic exposure to ionization radiation, even at low does, have shown to lead to several health conditions [2]. Cataracts, leukaemia, and several types of cancer have been linked to radiation exposure in certain populations, including radiation physicists and early radiologist who practiced before modern safeguards were in use [2].

The corner stone of our profession has always been ALARA, which has been the principle used to manage the patients and occupational exposure. Dosimetry is also mandated by the NCRP report 116 to maintain radiation exposure within limits. While the general public is allowed 500mrem (5mSv) for whole body dose, the radiation worker is allowed 10 times more than the general public, i.e. 5000 mrem (50 mSv). The NCRP report 116 also states another way to track cumulative occupational dose limits1000mrem (10mSv) times the age of person in years. They base the yearly dose limits to the specific body parts on the radio- sensitivity and the susceptibility to damage from ionizing radiation, with the lens of the eye limits being 15rem(0.15Sv) and extremities or skin of the entire body being 50 rem (0.5Sv). The Embryo exposure is given the same limit for general public and the radiation worker with it being 500mrem (5mSv) with each month of the pregnancy is 50mrem (0.5mSv) [2].

In addition, the number of procedures a technologist performs at their facility can also contribute to the exposure received. If protective gear is worn, the technologist will reduce their occupational exposure. The thyroid shield, lead eyewear and lead apron should always be worn when appropriate. The wrap around skirt and vest give the best protection as your back is covered also when you turn around. The height of the technologist can play a role in contributing to occupational dose exposure as the exposure is related to the size of the x-ray beam and the beam intensity and how close are the thyroid and eye lens. as Hybrid technology has brought about more non-tradition learning, which has brought gaps in the understanding of the technology and how it affects occupational dose.

Occupational Radiation protection is a shared responsibility by the Imaging Team. The ICRP established the fundamental principle of overall system of radiation protection. In justification, as related to occupational dose exposure, the technologist acts as a liaison to the radiologist and sometimes to the referring physician. It is important that the technologist reviews the patients chart and makes sure that if the indication doesn't fit with the protocols established or if the procedure is a duplicate procedure, they need to contact the radiologist. If the technologist works in a facility where there isn't a radiologist, they need to contact the referring physician to bring to his/her attention the issue and decide if they want to cancel the study. This ensures that duplicate exposure or unnecessary exposure doesn't happen. The technologist's responsibility dwells with the final exposure, so it is their job to ensure the protocol that has been establish is being used and the parameters are set correctly. Finally, with the optimization of protection the two fold approach includes the physicist playing the critical role of helping to design the room with the correct shielding and the technologist plays a critical role in using the correct protocol for the procedure.

With optimization of operating parameters of the imaging system the team approach also applies a technologist can perform the quality control each morning to ensure the camera is emits correct exposure. Along with this, the imaging team needs to establish a quality assurance program that includes quarterly QC, the physicist and technologist should perform together and yearly QC that the physicist should do to ensure equipment is working correctly. The technologist is the front line person that picks the dose and produces the image based on the protocol that was established. It is important that the technologist recognizes when their equipment isn't working correctly, so they can call the physicist or the service engineer. Of course, the imaging protocols should be established based on international guidelines and best practice based on the newest professional organizations that have produced these. Initial competencies and yearly training needs to include programs that show how exposures, practice and radiation protection can affect occupational dose.

The health care team should incorporate in their daily practice to reduce occupational Dose, which includes: Minimize fluoroscopy time and reduce the number of images you take. The radiologist can use small taps instead of continuous operation to contribute to lowering of the occupational dose. Tight collimation reduces patient dose and improves image quality by reducing scatter. C-arm position c-arm over the area of interest and close the collimation should be used as little as possible.

Another way to incorporate occupational dose reduction is to use patient dose reduction technology that is available in software packages for your equipment. This should be budgeted for new purchase of equipment, as well as installed on already existing equipment. This would include pulsed fluoroscopy, low dose rate settings, spectral beam filtration and use of increased x-ray beam energy.

The third way to reduce dose to the patient is to use good imaging chain geometry and position the patient as far away from the x-ray tube as possible, while placing the image receptor as close as possible to the patient. This method also reduces the scatter that will in turn reduce the occupational dose to the operator.

The fourth way is to ensure that your position yourself in the low scatter area by using power injectors when using contrast and step out of the room during fluorographic acquisition (digital subtraction) when possible. Always keep your hands out of the x-ray beam by using extension tubing and needle holders. When doing lateral's imaging, position yourself away from the direct beam, remembering that the highest scatter is located on the x-ray beam entrance to the patient. Incorporate in your protocol having the x-ray tubes positioned on the side opposite of the operator and try to avoid over the table x-ray tubes, to avoid elevated exposure.

The fifth way is to ensure that personal protective shielding is used to include aprons, thyroid shield, ceiling suspended shields, lead eyewear and when appropriate lead gloves. The best method for lead apron protection involve the use of the vest and shirt, as it allows the operator to move around freely and it also helps to distribute the weight more evenly. Because of the weight of the lead apron a weightless apron was developed on a rolling device, which moved as the doctor moved. There has been a new version developed that hangs from the ceiling. This version provides projection and reduces the ergonomic hazards. It is important to incorporate lead glasses with large lenses to reduce exposure to the eyes. This not only eliminates scatter from the side and from the operators own head in the field of view. When the hands are in the primary field of view with the lead glove, it should be noted that this would increase radiation dose due to the lead gloves. There have been some studies that show the use of disposable drapes that can reduce the exposure to the radiation worker by at least 12 fold to the eyes, 26 fold to the thyroid and 29 fold to the hands. Equipment mounted shielding includes protective drapes, which can be suspended from the table or from the ceiling. The table suspended drapes hang from the side of the patient table between the under table x-ray tube and the operator. The only time this doesn't work is when the x-ray gantry is in an oblique or lateral position. Ceiling shield can reduce dose to the worker when you have procedures that take a long time to perform. It has been shown that the use of Ceiling shields can contribute to the reduction of dose to the lens of the eye [3].

The sixth ways to reduce occupational dose is to ensure that an adequate Quality assurance and Quality Control program has been established, which includes the optimization of the imaging system. Using generic protocol can increase exposure to both the patient and the worker. Protocols should be established with the consideration given to the patient's size and age, while incorporating dose reduction technology. All equipment should be maintained, and quality assurance and Quality control should be up to date to ensure that the doses delivered are correct.

Finally, management plays a role in reduction of the occupational dose by having the appropriate resource to incorporate all the above recommendations as well as having protocol's and policies in place to monitor dose exposure. Management is also responsible for ensuring that the quality assurance program is set up and running appropriately and includes dose monitoring, protective aprons examination review and acceptance testing on all equipment including personal protective wear by a physicist.

For safety and best accuracy of tracking of occupational exposure with badges, it should be noted that the badges should be worn at the same place every day. The NRCP recommends that the badge should be worn at waist or Chest level. If you have a lead apron on the badge, it should be worn at neck level. Pregnant workers should wear a second badge at the abdominal area under the shield. If a person is working in nuclear medicine, extremity dosimeters or ring badges should be worn.

Within the modality of Diagnostic Radiology your image is captured on CR, DR or film Cassettes and the same radiation protection applies here. A control booth should always be incorporated into the construction of the room to ensure that the exposure is kept to a minimum. The control panel should have an exposure button that is connected to a cord that is very short to ensure the technologist can't stand in the room when taking the exposure. The x-ray tube should never be pointed to the doorway or the control booth. The technologist should never hold the patient and a different hospital staff or family member should assist if needed, but the protective gear should always be worn including lead apron, thyroid shield and leaded eyewear. Portable machine should have a 6 foot extension cord for exposure, so the technologist can stand at a 90 degree angle to the primary beam to lower the amount of occupational dose received from scatter.

Nuclear medicine works differently than diagnostic radiology, as the radiation is given to a patient by injecting in the IV, inhalation of the radioactivity or by swallowing the radioactivity in a pill form or liquid. The best defence for reduction of the occupational exposure is to wear a lab coat, glove, use tongs and the correct lead syringe shield appropriate to the energy level of the isotope given to the patient. Special attention should be given when working with I-131 and the technologist should ensure they are working in a negative pressure room under a film hood, to ensure they don't ingest any isotope when drawing up the dose for the patient.

In case of CT you can reduce the dose to the patient and decrease the scatter by incorporating tube modulation and optimizing the tube current. Using a power injector when administering contrast will ensure you don't have to be in the room which will contribute to reducing exposure to the technologist. Tight collimation will also reduce scatter, which in turn reduces occupational dose exposure. The use of post processing also helps to reduce occupational exposure.

A team approach with the radiologist, physicist and the technologist working together and by following the radiation protection rules, i.e. Time, Distance and Shielding the health care team can ensure that their occupational dose is as low as possible achievable.

Challenges that still remain include better QA and QC standardization that is needed in all countries. The gap in the existing radiation protection programs needs to be closed. It also needs to be ensured that all workers have access to radiation protection devices including lead aprons, thyroid shield and lead eye wear. Finally, the IAEA needs to continue to produce non-traditional education material available that can be downloaded on the new hybrid technology including information related to how practice in this field affects occupational dose exposure.

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A MEDICAL PHYSICIST'S PERSPECTIVE

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Abstract

The use of new technologies such as fluoroscopy image-guided interventional procedures applied to the diagnosis and treatment of diseases can result in high radiation doses to patients and staff, depending on the complexity of the procedure and factors related to the patient characteristics. Where there is a demand for jointly managing patient and staff radiation protection, within an integrated approach, the medical physicist can contribute to the continuous quality improvement of the overall process, by relying on radiation protection culture within an active and proactive inclusion and participation of the staff.

INTRODUCTION

Radiation protection of the worker is still a challenge in some clinical practices. It has well been shown that the dose received by the staff during procedures of fluoroscopy, interventional radiology and cardiology, varies with the procedure used, the complexity and the factors related to the patient and it can lead to quite high doses, with an expected increase in the the eye lens dose and in tumor risk [1, 2]. For a pregnant staff member, a restriction to the occupational exposure is introduced, while ethical issues could arise [3]. Some medical specialties, which can usually be found outside imaging departments or facilities, such as gastroenterology, urology, vascular surgery and others, they have long been using fluoroscopically guided interventional procedures, as an alternative to more invasive and complex open surgery approaches, and in these cases they could be in the position of not having the tools of radiation protection which are normally used in laboratories specifically dedicated to interventional surgeries.

Procedures performed for pediatric patients, such as interventional cardiology, could have the characteristics for a higher dose to the staff, since the effect of lower dose from radiation scattering, compared to an adult patient, is overcome by the complexity of the operating framework, which, in particular, may require a longer procedure and closer to the patient physical presence, resulting in a logistical difficulty to use protection tools. Moreover advanced technologies, such as biplane imaging systems are introducing an additional source of doses for the staff [4,5].

Some surveys have shown low doses to the staff operating under routine conditions, however, it must be taken into account that during these studies there is a tendency to maintain good protection levels, which generally seems not to be maintained always in the daily practice, in interventional laboratories, where often there is incorrect use or even not use at all of the personal dosimeter [6] .

AN INTEGRATED MANAGEMENT OF PATIENT DOSE AND STAFF DOSE

The principles of justification and optimization of protection consider, in the context of medicine, not only the dose to the patient, but also to the staff. The training aspects are always an open issue to all professionals. Technicians, nurses and medical specialists, working in interventional radiology, cardiology and in the various specialties, derive benefits from a specific training on their activities, and, if supported, from consulting advises aimed to optimize aspects and practices of radiation protection addressed to both the patients and the workers. It is well known that medical physicists are radiation experts, since the application of radiation physics in the medical field, is part of their specialty [7, 8]. The European Guidelines on Medical Physics Expert [9] report the Qualification Framework and Curricula in the Medical Physics area, related to radiological devices and protection from ionizing radiation in diagnostic and interventional radiology, radiation oncology and nuclear medicine. The knowledge provided by the curricula for radiologists and interventionalists about physics, radiation risks, radiation protection and dose evaluation is far less than the knowledge of medical physicists [10]. In this sense could be useful to take advantage, in all countries, from the involvement of the medical physicists in the teaching activities to the medical students, as far as radiation risks and radiation protection are concerned. The use of new techniques such as fluoroscopy image-guided interventional procedures, performed for the diagnosis and treatment of disease, can result in high radiation doses to patients and staff. Moreover, a low dose to the patient does not always go hand in hand with a low dose to staff members. In cases where a reduction of the dose to the patient can lead to an increase in the dose to the staff, or in the opposite situation, ethical issues are arising which require particular attention by the medical physicist and by the qualified expert (or by an individual recognized as both) as well as by staff itself. There is a need to enable a real process of integration [10] where clinical benefits of the used procedures: take into account the levels of radiation safety for patients and staff; include the quality assurance dose assessment jointly for the staff and for the patient and where the radiation protection for staff and patients are to be seen as a single issue.

THE PATH FORWARD

The growing use and increasing complexity of interventional radiological and cardiological procedures have led to an increasing patient dose and at the same time to an increasing concern over the staff doses. The judgment on the conduct of any procedure is made by the physician after considering all circumstances related to the specific clinical situation. A margin for optimization aimed to reduce doses it is definitely there. There is an arising demand for the management of radiation risks for patients and staff, as an integrated approach, where the medical physicist contributes to the continuous quality improvement of the overall process, by relying on radiation protection culture within an active and proactive inclusion and participation of the staff.

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A REGULATOR'S PERSPECTIVE

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Abstract

The performance of a great variety of procedures in the medical practice every day generates occupational exposure to ionizing radiations, therefore an adequate protection of the workers involved is essential for ensuring a safe and acceptable use of these radiations. This paper presents a regulatory perspective to the different angles of occupational radiation protection in the medical practice.

INTRODUCTION

The performance of a great variety of procedures in the medical practice every day generates occupational exposure to ionizing radiations, therefore an adequate protection of the workers involved is essential for ensuring a safe and acceptable use of these radiations.

THE REGULATORY PERSPECTIVE TO THE OCCUPATIONAL RADIOLOGICAL PROTECTION

The applications in the medical practice require, at least, the existence of a Regulatory Authority (RA), supported by an appropriate regulatory framework clearly defining the safety requirements and criteria applicable to the occupational radiation protection, and bearing into account the need for availability of agile mechanisms that allow updating of the regulations, in the context of sustained technical and technological advances.

However, it is not unusual that the regulation of the radiological protection in the medical practice is exercised in a way shared between more than one regulatory authority. This situation can create ambiguities, overlapping, and operative and functional difficulties for the control of the occupational exposure, as well as an excess of bureaucratic burden on the user.

Additionally, the competent RA should establish a nationwide, effective and sustainable program, aimed at the occupational radiological protection, defining the criteria for its optimization, the guidelines for the restriction of radiation exposure, as well as all the infrastructure and technical requirements needed for its achievement, development, and sustainability.

An effective regulatory program for the control of the occupational exposure requires, among other aspects: the cooperation between the competent RA and the Health Regulatory Authority (even in the applications where the Ministry of Health is not the competent regulatory authority), as well as with other institutions that may contribute to this objective, such as the competent authority in education, universities and other academic institutions, professional societies (radiotherapy, nuclear medicine, radiology and others), the society of radiological protection, dosimetric services and laboratories for dosimetric calibration, etc.

The RA should assume a proactive role in the design of this strategy to ensure the follow-up and adequate implementation of whichever program conceived and of the relevant cooperation agreements thereto.

A significant aspect to keep in mind in the control of the occupational exposure in the medical practice, is the dynamics of the technical and technological progress, which occurs at amazing speed and is a significant challenge, not only for the personnel directly involved in the practice, but also for the personnel of the RA. Therefore, an effective and efficient performance of the AR, would require:

- properly qualified and trained staff, knowledgeable of the latest advances in the medical technology using ionizing radiations; and
- the adequate number of staff and proportional to the nationwide development and scope of the radiological medical practices introduced.

Another aspect to consider, is the wide spectrum of sources associated to the different radiological medical practices, as well as the important variation in the technical and technological complexity, and the range of associated doses which raise a need for defining risk based requirements, which will allow the RA to maximize its efforts optimizing its financial and human resources.

There are different technical, normative, and financial weaknesses, also in the national infrastructures that hinder the process of implementation of the requirements on occupational radiological protection. Among these are:

- Insufficient human resources appropriately qualified at the facilities;
- RP equipment obsolete and, on occasions, insufficient;
- Non-existence of cooperation relationships and coordination among regulatory authorities and with the other institutions involved in the operational radiological protection;
- Inconsistencies, duplicity and contradictions in the regulations dictated by the regulatory authorities (where there is more than one);
- Inefficient mechanisms for upgrading of the regulations in a context of sustained and vertiginous technical and technological advances;
- Significant hierarchical differences among the different regulatory authorities, which can also mean significant differences in the provision of resources;
- Limited scope of dosimetry services and non-compliance with the international standards;
- Individual radiological surveillance non-commensurate with the radiological risks;
- Little development in safety culture;
- Non-existence of quality management systems in the dosimetry services;
- Radiation Protection Programs are not formally implemented at the institutions and
- Insufficient size or nonexistence of infrastructures on metrology.

The experience has demonstrated that entities with similar characteristics, from the radiological point of view, often have very different outcomes in occupational radiological protection and in the application of the ALARA principle.

CONCLUSIONS

The improvement of the regulatory control in occupational radiological protection requires:

- A detailed analysis of the aspects that hinder the execution of the safety regulations and requirements;
- A RA with permanent self-assessment attitude for the adequacy of its program; and
- A RA provided with enough human resources, with qualification and training commensurate with the medical practices introduced.

The implementation of an appropriate management system and fostering of a safety culture bear a significant contribution towards the achievement of the occupational radiological protection objectives in the medical practice.

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A MANUFACTURER'S PERSPECTIVE

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In general, usage authorisation is under the responsibility of qualified persons: Qualified Experts, Radiation Protection Officers, Qualified Operators, Qualified Health professionals (BSS - Safety Series No. GSR, Part-3, IAEA). Some regions require testing before the first use of a new equipment through Authorized Persons. A currently well-known case is for Europe under the application of the EU COUNCIL DIRECTIVE 2013/59/EURATOM. Today, the interpretation of the standards and guidelines in case of new equipment is too much dependent on the Qualified Expert and this is prone to error. In the developing countries, it is common that the Government is adopting a policy of accepting devices that are manufactured in compliance with the regulations of another country. (e.g. Australian, Canadian or Japanese License, devices with a European "CE" mark, or devices that have been granted marketing clearance by the US-FDA.

Radiation protection standards are currently maintained by the existing International Scientists Committees and User Experts, novelty equipment is mostly abandoned and the need to be put it into service suffers from the lack of commonly approved safety and performance criteria, e.g. for the European Union, the new RP 162 does not include criteria for Particle therapy (only LINACs are covered in Radiotherapy).

Particle Therapy does exist and will be treating more and more patients around the world in the coming years:

- Dutch report "horizon scanning report on Proton Radio- reference U-5638/MB/JvK/785-A of the Health Council of the Netherlands dated on December 14, 2009
- An evidence based review of proton beam therapy: the report of ASTRO's emerging technology committee - 2012 Apr;103(1):8-11. doi: 10.1016/j.radonc.2012.02.001. E. pub 2012 Mar 9.

CONCLUSIONS

Due to the trend in development of Particle Therapy and the continued globalization of the free-market economies and the integration of the emerging economies, Governments are encouraged to follow the growing movement towards harmonized regulatory systems. Acceptance criteria are subject to the adjustments from each Qualified Person (QP) in RP, or an Accredited Competent Laboratory (CL) in RP, who are established in each different country. This contradicts to the current trend of internationalization and harmonization of best practices in Radiation Protection.

Consensus standards should be defined and promoted by the IAEA for Particle Therapy and an organization should be developed at an international level to allow access to this new Cancer treatment modality, even for developing countries.

An international co-operation organisation for Accreditation of QPs in RP and CLs in RP (e.g., under IAEA authority) should be installed as a network of nationally recognised accreditation bodies:

- To maintain a system of mutual recognition between accreditation schemes and reciprocal acceptance of accredited conformity assessment services and results; and
- To manage a peer evaluation system consistent with the international practices.

THE PERSPECTIVE OF THE MEDICAL PROFESSIONAL ASSOCIATIONS

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Abstract

Strengthening of occupational radiation protection (ORP) in the health care system and radiology facilities is a team event and responsibility; radiologists play leading and decision-making roles in radiology facilities to improve the outcome through teamwork and an integrated workplan. The ISR and radiologists worldwide are committed in improvements of occupational radiation protection in the next decade and beyond. As a key stakeholder representing 80+ radiology organizations, the ISR looks forward to collaborating with the IAEA and other stakeholders, contributing to the development and facilitating the implementation of system-wide ORP recommendations and actions.

THE SPECIFICS OF MEDICINE AND RADIOLOGY

Professional organizations and radiologists are committed to the safe use of radiation in medicine to protect patients and workers [1]: both components are equally important and involved through the whole workflow of a patient's examination. In X-ray imaging, professional exposure is most significant in fluoroscopy-guided and CT-guided intervention where better patient protection usually equals better occupational protection.

THE PRACTICAL APPROACH TO DAILY OCCUPATIONAL RADIATION PROTECTION IN RADIOLOGY

Simple practical rules serve the daily working procedure: the three principles governing occupational protection are short exposure time, maximal distance, and adequate shielding. To limit scatter radiation, the personnel's position should be opposite to the tube (on the detector's side), and the tube should be under the table. Shielding includes the apron (0.25mm Pb with overlap anteriorly), lead glasses, thyroid shield, table curtains, lateral patient shields, ceiling-suspended screens and/or mobile floor shielding. Personal dosimetry in intervention requires two dosimeters (one below the apron at chest level mainly reflecting effective dose, and the other above the apron at neck or eye level used for estimating the dose to the lens). Real time dosimetry affords an immediate feedback and supports education. Using these measures, occupational effective dose can be kept well below legal limits.

SPECIFIC SITUATIONS ASKING FOR SPECIAL ATTENTION

Recent research has shown that the sensitivity of the lenses of the eyes is higher than assumed during decades and that the dose limit has to be much lower. Special attention, thus, is required to keep the dose to the lenses as small as reasonably achievable [2]. Similarly, in case of direct exposure of the interventionalist's hands, additional measures are required to minimize direct exposure and an additional finger ring dosimeter is needed. Standing rules guarantee that pregnant personnel will not reach the legal limit of 1 mSv at the uterus during the rest of pregnancy.

CURRENT AND FUTURE NEEDS

Occupational radiation protection in medicine heavily depends on both education and practical training of practitioners and regulatory strengthening in health care systems. There are many opportunities in these areas, and a systematic approach is needed to define the specific knowledge, the skills and the competences to be acquired by each professional member of the medical staff in radiology and all other medical institutions using ionizing radiation; the European Union has used this approach [3]. To strengthen occupational radiation protection in the next decade, a comprehensive approach is required, as recommended in the Bonn Call for Action and EuroSafe Imaging Call for Action [4,5] These actions include promoting awareness, conducting research, providing training, strengthening infrastructure (access to and proper use of protective devices), implementing effective policies (operator certification), impact evaluation and on-going improvement.

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CHAIR'S SUMMARY OF ROUND TABLE 3 – OCCUPATIONAL RADIATION PROTECTION IN MEDICINE – THE WAY FORWARD

Participants: Donna Newman, Marie Claire Cantone, Ramon Hernandez Alvarez, Michel Baelen, Peter Vock, Renate Czarwinski, Renato Padovani (chair)

Occupational exposure in medicine has a distinctive characteristic when compared to other fields: the exposure of the worker is frequently related to patient dose. The radiation protection (RP) practice for worker and patient are today regulated by separate norms, impeding a harmonised implementation of the justification and optimisation processes.

Another specificity is the fast-evolving radiological technologies and practices, e.g. radiation therapy with the use of high energy particle and alpha particle emitters; imaging technology, one of the most important developments in medicine in the last decades, not only used for diagnostic purposes but also to guide therapeutic mini-invasive procedures.

As an impact on occupational exposure from the extensive use of radiological equipment outside the radiology department, today the high dose exposed workers are in large part clinicians and nurses, in addition to traditional radiology departments. For these workers, the high individual doses are mainly due to: (i) little or no RP education, (ii) poor compliance with RP and personal monitoring rules, (iii) the use of fluoroscopy equipment not designed for complex and high dose interventional procedures.

In the round table discussion, there has been a consensus on the increasing concern about potential radiation deleterious effects and attention for a more adequate RP. The evidence of non-cancer radiation risks, cataracts and cardiovascular effects, emphasizes the relevance for a reduction of staff and patient dose.

The representative of the International Society of Radiology (IRS) highlighted the need of an effective education and training of health professionals, trough accredited programs and individual certification of competences. This is a prerequisite to foster teamwork and to implement a safety culture. In the teamwork the radiographer, as underlined by the representative of the International Radiographer Society (ISRRT), should contribute to the development and the implementation of optimized procedures that take into account worker's exposure.

Medical physicists highlighted the rising demand for the management of radiation risks for patients and staff, as an integrated approach, where the medical physicist contributes to the continuous quality improvement of the overall process and where the medical physicist is recognized, by the regulation, as the competent professional that can assure a harmonized approach to the protection of patient and staff.

Manufactures, active in the development of new and advanced imaging and therapy technologies, are requiring a prompt answer from the regulators in the release of internationally recognized safety standards and acceptance criteria of the equipment and, for their rapid availability in the clinical practice. It is recommended to setup a system of mutual recognition between accreditation schemes and reciprocal acceptance of accredited conformity assessment services and results.

The representative of the Regulatory authorities (RA) highlighted several limitations that can impede, mainly in low and medium income countries, an effective support to the RP process: low cooperation and coordination and duplication of RA, inefficient mechanisms for upgrading the regulations and insufficient implementation of RP programs in hospitals. On the side of technical infrastructures obsolescence of instrumentation, insufficient metrology infrastructures, limited scope and non-compliance with the international standards of dosimetry services were mentioned.

IRPA is recognized by its members, stakeholders and the public as the international voice of the radiation protection profession in the enhancement of radiation protection culture and practice worldwide. Its representative recalled that in the joint objectives of the 2012 Bonn conference there was yet a request for a 'RP fully integrated in health care settings'. IRPA is fully devoted to sustaining this objective by developing guidelines in cooperation with international organisations (IAEA, WHO, etc.) and professional societies (IOMP, etc.), on general issues, e.g. implementation of RP culture and education and training, and technical issues, e.g. eye dose lens dosimetry. IRPA is ready to cooperate and offer the platform for fostering public consultation, disseminating information, for the development of education and training platforms, scientific seminars and symposia and the improvement of standards.

In summary the conclusion and recommendations from the round table discussion are as follows:

- Medical exposure has a unique specificity: the occupational exposure is related to patient exposure.
- A harmonized approach to the RP of workers and patients is essential for the application of the justification and optimization principles, taking into account the two exposures. A harmonized approach will require a specific regulation and the promotion of the RP teamwork.
- An effective education and training of health professionals, nowadays performed nearly as often outside as inside the departments of radiology, requires accredited programmes and individual certification of skill and competences acquired.
- Rapid development of imaging and therapy technologies, providing great benefit to the health of the population, is requiring a prompt answer of the regulators in the release of international safety standards and acceptance criteria of equipment for their availability in the clinical practice. Manufacturer associations (e.g. COCIR) should support developments.
- IRPA and IAEA, in collaboration with WHO, IOMP, ISR and ISRRT, are supporting inter-professional collaboration setting up working groups aiming to revise safety standard for the medical sector, to support the implementation of the new eye-lens dose limits and, in general, to promote the safety culture and an ethic approach to RP in medicine.

ROUND TABLE SESSION 4:

CHALLENGES IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION

Chairperson: R. Cruz Suarez, International Atomic Energy Agency

CHALLENGES IN IMPLEMENTING OCCUPTIONAL RADIATION PROTECTION IN AFRICA

F.A. Ollite

Radiation Protection Authority, Mauritius

During the past decades, there has been a significant increase in the number of nuclear applications involving radiation sources all over Africa, both in the human health and industrial sectors. These nuclear applications require special attention, considering the high number of workers involved and the risks associated with operating facilities that involve new medical and industrial technologies. Most African countries did not have a proper radiation protection infrastructure in place and, in particular, no occupational radiation protection infrastructure, and this was a serious problem.

There has been an unprecedented international co-operative effort during the past two decades to improve radiation and waste safety infrastructure in the African Member States. This mainly started with the IAEA's Technical Co-operation Model Project on Upgrading Radiation Protection Infrastructure. African Member States benefitted significant assistance from the IAEA, through their participations in the Model Project, for the upgrading their national radiation protection infrastructures, including the establishment of occupational exposure control. Despite the fact that much has been achieved under the Model Project, there is still a need to further strengthen the national systems in many African countries for the protection of health and safety of workers who are occupationally exposed to radiation to ensure compliance with the requirements of the IAEA International Basic Safety Standards. A number of incidents have resulted in overexposure of workers managing radioactive sources, demonstrating the need to reinforce radiation safety practice in workplaces across the region.

The IAEA regional technical cooperation project RAF/9/043: *Strengthening the Transfer of Experience Related to Occupational Radiation Protection of the Nuclear Industry and Other Applications Involving Ionizing Radiation* was thereafter established to help African Member States to further strengthen and sustain their national occupational radiation protection infrastructure. The project was mainly aimed at promoting networking and the exchange of experience at the international level for a harmonized approach in implementing the International Basic Safety Standards requirements on Occupational Radiation Protection. The project has provided continuous support to promote effective radiological protection monitoring in occupational exposure. The impact of the project was rather substantial as there has been significant progress made by most African counties for the establishment of sustainable occupational radiation protection infrastructure. However, none of these countries has fully met the requirements of the IAEA International Basic Safety Standards and related safety guides on occupational radiation protection. They are all facing various challenges to achieve this objective, and the most common ones are highlighted below.

CAPACITY BUILDING

Despite the fact that strong efforts are being made by all African Member States, capacity building to ensure a sustainable development of the national radiation safety infrastructure still remains a challenge for many of these countries. This is mainly due to a lack of adequate human and financial resources. The IAEA, through its technical cooperation programme has provided significant assistance for capacity building in the region. However, there are still some gaps in many countries which need to be addressed for a sustainable occupational radiation protection infrastructure.

MAINTENANCE OF A STRONG SAFETY CULTURE

A strong safety culture is a key for a sustainable occupational radiation protection infrastructure. Many African countries are facing difficulties in maintaining a strong safety culture. This can only be achieved through effective training programmes for all workers involved in the use of ionizing radiation.

IMPLEMENTATION OF RADIATION PROTECTION PROGRAMMES AT END-USER FACILITIES

The effective implementation of radiation protection programmes at the end-user facilities requires a strong and effective national regulatory infrastructure for radiation safety. Almost all the African Member States do have a regulatory system in place, but in many countries the system is not fully effective. It is therefore essential to maintain an international co-operative effort to further strengthen the national radiation safety infrastructure in the African countries.

PROVISION OF A QUALITY DOSIMETRY SERVICE

There is a limited number of dosimetry service providers in most African Member States. In many of these countries, there is only one service provider, and in most cases this service provider only provides for external dosimetry. Another common challenge in the region is further develop capabilities for quality dosimetry service to also include extremity and internal dosimetry. Regular inter-comparison exercise is important to improve and benchmark the quality of the dosimetry service.

DOSE RECORD MANAGEMENT OF OCCUPATIONAL RADIATION EXPOSURES

Most African Member States does not have an effective dose record management system to manage the radiation exposures of workers. Some of them are basically using the Excel software to keep record of the occupational radiation doses, and some others are also trying to customize the Regulatory Authority Information System (RAIS) software developed by the IAEA to be used as a dose record management tool.

Under the ongoing technical co-operation project RAF/9/053: *Strengthening Technical Capabilities for Patient and Occupational Radiation Protection in Member States*, the IAEA is further assisting the African Member States to meet these common challenges for the establishment of a sustainable occupational radiation protection infrastructure. African countries are now working on aligning national radiation protection programmes with the requirements of the IAEA International Basic Safety Standards and related safety guides.

The Forum of Nuclear Regulatory Bodies in Africa (FNRBA) has also contributed to strengthen the networking within the African region for a harmonized approach in the implementation of the requirements of the International Basic Safety Standards, by fostering experience sharing and identification of the best practices for the efficient and effective implementation of these requirements.

It is essential to maintain and synergize the international co-operative efforts to meet the above challenges in implementing occupational radiation protections in Africa and to further strengthen the radiation safety infrastructure in the region.

CHALLENGES IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION IN ASIA

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The Asia-Pacific Region ALARA Network (ARAN) was established in 2007 under the framework of Regional Collaborative Agreements.

The main objectives of the ARAN are:

1) To support the development of a sustainable regional network, which facilitates information, findings and data exchange and practical and cost effective implementation of the principle of optimisation of radiation protection in participating countries.
2) To maintain, enhance and develop competence and skills in radiation protection, with special emphasis on the implementation of the ALARA principle for occupational exposures in routine operations.
3) To contribute to the harmonisation of objectives, standards and practices, particularly concerning ALARA, within participating countries.
4) To contribute to the effective use, exchange and integration of skills and expertise across Member States.

The activities of the network are intended to cover all types of civilian practices within the different sectors: nuclear, industrial, medical, research, and work with naturally occurring radioactive materials (NORM).

A series of workshops were held:

- The First Workshop on "Improving Radiation Protection in Industrial Radiography" in Chiba, Japan, November 2008;
- The Second Workshop on "Improving Radiation Protection in NORM Producing Industries" in Beijing, China, October 2009;
- The Third Workshop on "Occupational Exposure in Medical Applications" in Adelaide, Australia, October 2010;
- The Fourth Workshop on "Occupational Exposure in Emergency Situation" in Chiba, Japan, November 2011;
- The Fifth Workshop on "Occupational Radiation Protection and ALARA in Waste Management" in Daejeon, Korea, July 2014; and
- Each workshop conclude with recommendations to improve radiation protection situation to IAEA, Member States, and the Network itself.

In 2011, ARAN made successful shift to a TC Framework. Although ARAN has not been able to be fully self-sustainable, it could be evaluated as taking a great step forward in building up the radiation protection infrastructures.

CHALLENGES IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION IN LATIN AMERICA

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I think that all stakeholders involved in any way with the use of material or radioactive substances should share the challenges to the implementation of occupational radiation protection in Latin America.

Who are these actors? Stakeholders?

WORKERS

Let us start with the workers. We speak on behalf of worker protection and can hardly see the region associations that are looking to seriously participate in the debate on occupational radiation protection. In most cases the aim is only financial benefits, these entities do not see the employer as a partner. According to the International Basic Safety Standards General Safety Requirements Part 3 as shown Requirement 22: Compliance by workers - Workers shall fulfil their obligations and carry out their duties for protection, I reproduce below:

"*3.83. Workers:*

(a) Shall follow any applicable rules and procedures for protection and safety as specified by the employer, registrant or licensee;

(b) Shall use properly the monitoring equipment and personal protective equipment provided;

(c) Shall cooperate with the employer, registrant or licensee with regard to protection and safety, and programmes for workers' health surveillance and programmes for dose assessment;

(d) Shall provide to the employer, registrant or licensee such information on their past and present work that is relevant for ensuring effective and comprehensive protection and safety for themselves and others;

(e) Shall abstain from any wilful action that could put themselves or others in situations that would not be in accordance with the requirements of these Standards;

(f) Shall accept such information, instruction and training in protection and safety as will enable them to conduct their work in accordance with the requirements of these Standards.

3.84. A worker who identifies circumstances that could adversely affect protection and safety shall report such circumstances to the employer, registrant or licensee as soon as possible."

So, I think it's time that workers begin to participate more actively, synergistically, positively, together with employers in improving occupational radiation protection. Trade unions and professional bodies must also act to participate in the training and development of manpower process. Why not use part of the Union's budget for training programs and information across the workforce?

SERVICE PROVIDERS

Service providers are:

- Individual monitoring;
- Equipment Calibration;
- Training and Education;
- Qualified Experts; and
- Those who provide some kind of service in the field of radiological protection in general and particularly in occupational radiation protection.

The first step is to obtain accreditation for their activities. In the case of testing laboratories to ISO-IEC17025, in the case of training and education IEC ISO-9001, ISO-IEC 17020 for qualified experts, etc.

Other challenges noted in the region are:

- Dosimetry of the lens - methodology, calibration, geometry, occupational control;
- Dosimetry extremities - fingers and wrist;
- Approval of using active dosimeters - especially in practices with high doses; and
- National Register of Doses.

END USERS OR REGISTRANTS

Can we separate the end users by practices: nuclear, industry, medicine, etc.

However, what are the challenges for them?

I would say we should start with maintaining an ORP structure in accordance with the magnitude of the installation. Provide an adequate budget for the occupational radiation protection, training, equipment appropriate and sufficient in number.

To inform the entire task force about the risks of the practice, it is very important that everyone has a minimum of information about what happens in the business and the associated risks. Remember, workers, everyone must cooperate with the employer.

Implement optimization programs and safety culture. There is an inadequate understanding of optimization.

Keep the workforce, trained, enabled and empowered.

Encourage, stimulate the task force to take part in the decisions concerning the ORP.

Be cooperative with the Regulatory Authority. Usually the reporting of incidents and accidents are incomplete.

REGULATORY AUTHORITY

The challenges for Regulatory Authority are:

- Support the implementation of all previous actions;
- Implement a legal framework in accordance with the magnitude of risk of existing practices in the country;
- Maintain structure inspection and enforcement in accordance with the magnitude of existing practices. Missing legislation - fines for accidental doses;
- The performance through inspections is not enough. Inspectors are not well prepared and trained, generally;
- Actions to obtain the commitment of Registrants to collaborate with the Regulatory Authority;
- Training and retraining the RA’s workforce to understand the local requirements;
- Acting and partnership with other organizations in order to provide requirements for authorization of service providers. Infrastructure is not capable and sufficient to authorize the operation of monitoring and calibration services;
- Promote, in conjunction with health authorities, means and trained personnel for the treatment of radiation injuries;
- Find a TSO that gives support to the strengthening of ORP in the country;
- Consider practices involving NORM;
- Understand that it is not necessary to have experts in all areas to do something and secondly the fact of not having a specialist is no excuse for doing nothing.

CHALLENGES IN IMPLEMENTING OCCUPATIONAL RADIATION PROTECTION IN CENTRAL EUROPE

K. Petrova

State Office for Nuclear Safety, Czech Republic

CURRENT SITUATION IN EUROPE IN RADIATION PROTECTION

European countries (members of EU and candidates' countries) have currently national legislation based on the Directives 89/618/Euratom, 90/641/Euratom, 96/29/Euratom, 97/43/Euratom and 2003/122/Euratom. Directive 96/29/Euratom establishes the basic safety standards. The provisions of that Directive apply to normal and emergency situations and have been supplemented by more specific legislation. All legislation in principle is based on ICRP 60 (1990), IAEA BSS (SS115) and other IAEA Safety Standards.

EUROPEAN COUNTRIES – FUTURE CHALLENGES IN RADIATION PROTECTION

European countries are currently in the stage of preparation of new legislation based on new IAEA BSS - General Safety Requirements Part 3, IAEA, 2011. There is also in preparation the IAEA Safety Guide on occupational radiation protection. IAEA also organizes IRRS missions with the aim to check a compliance of national legislation with IAEA Safety Standards (GSRPart 1– 7).

IAEA RASIMS is helping countries and providing an overview of countries status with respect to the compliance with IAEA SS (TSA2 focused to occupational exposures).

European countries have to respect and implement the Directive 2013/59/EURATOM of 5 December 2013, laying down basic safety standards for protection against the dangers arising from exposure to ionising radiation. Member States shall bring into force the laws, regulations and administrative provisions necessary to comply with this Directive by 6 February 2018.

OCCUPATIONAL RADIATION PROTECTION IN EUROPEAN COUNTRIES

Basic principles for occupational protection are established in Dir.29/96 and Dir 641/90 Euratom - „Outside“ Workers (IAEA called as „Itinerant“ workers) established responsibilities for the protection of worker performing work in controlled area operated by another person than his/her employer.

European Commission launched an European Study on Occupational Radiation Exposures (ESOREX) – surveying changes in the personal doses after implementation of Directive 29/96/. The project continues with aim to establish a sustainable platform for exchange of information in the field of occupational safety within the Europe.

European Commission (EC) established also an European ALARA Network (EAN) in 1996, to support further specific European research on topics dealing with optimization of radiation protection, as well as to facilitate the dissemination of good ALARA practices within the European industry, research and medical sectors. After the end of the financial support of the EC, in 2005, EAN became self sustainable as a non-profit association under the French law. 20

countries are participating to the network, which is coordinate by CEPN (France) and PHE(UK). http://www.eu-alara.net/.

EC also initiated development and published Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation (Radiation Protection, No.160,2009).

IAEA created for non-EU countries the Regional European and Central Asian ALARA Network (RECAN). The objectives of RECAN was to support the development of a sustainable regional network, which facilitates information exchange and an integrated approach to practical and cost-effective implementation of the principle of optimization participating Member States. http://recan.webplus.net/

NEW CHALLENGES IN OCCUPATIONAL RADIATION PROTECTION IN EUROPE

European Countries are facing a challenge to implement both standards European legislation as well as IAEA Safety Standards. As the base is identical – ICRP 103 – the interpretation and goals are in some areas different. There are new general common issues, such as introduction of exposure situations which are replacing practices and interventions, new limit for lens of the eye – average dose 20mSv/y(100mSv/5y and 50mSv/y), still unsolved problem related to practical application and monitoring, optimization is more emphasized with more specific requirements for dose constraints – in the case of dose constraints for occupational exposures, they will be set by the operator, however levels are still to be discussed.

On the other hand there are some specific and slightly different requirement in European legislation - new limit for radiation workers is introduced as 20 mSv/y with possibility only to authorize 100mSv/5y (this could be helpful for some professions or workplaces such as uranium mines), definition of radiation worker – when exposure can exceed 1mSv/y, categorization of radiation workers – A and B, outside workers – definition is expanded not only for category A and not only for controlled area, NORM workplaces are identified as planned exposure situations in the European directive – it means licensing, categorization of workers, evaluation of doses, if exceeding 6mSv there are specific requirements for workers protection, application of limits is required. Concerning radon in workplaces – this is an existing exposure situations, but there is requirement for estimation of doses in all workplaces located in basement or first floor in specified radon prone areas – this is not clear how to define, there is also difference in reference levels in EU legislation (300 Bq/m^3) and IAEA standards (1000Bq/m^3). For emergency workers – professionals (members of integrated rescue systems, soldiers), but also for volunteers there is health surveillance and dose record required and reference levels (RL) are again different – 50mSv (IAEA), 100mSv (EU). The requirement to take actions with potential to reach this level voluntarily could be a problem for fire fighters, policeman, soldiers.

During next few years it would be strongly recommended to make a common effort to implement all standards as far as possible in a similar way. EC already initiated project to identify common issues and organized a series of WS to enable an exchange of views (2015 – 2016). HERCA (the Heads of European Radiation Competent Authorities) created a specific task force to analyze issues and charged its working groups with focus on the implementation of these specified issues into national legislation.

New IAEA regional project (RER9128) was launched in 2014 “Strengthening National Capabilities for Radiological Protection of Workers and Occupational Exposure Control”. IAEA assistance under the project will make use of all available modalities for regional TC including expert advice, meetings and training including capacity building through national training courses and workshops, national consultants' meetings, standard training material and relevant IAEA publications.

TECHNICAL COOPERATION PROGRAMME AND THE OCCUPATIONAL RADIATION PROTECTION APPRAISAL SERVICE

R. Cruz Suárez, J. Ma

International Atomic Energy Agency

IAEA SAFETY FUNCTIONS

The IAEA is an independent intergovernmental, science and technology-based organization, in the United Nations family, that serves as the global focal point for nuclear cooperation. The IAEA safety function is to develop nuclear safety standards and provide for implementation in Member States. Based on these standards, the Agency promotes the achievement and maintenance of high levels of safety in applications of nuclear energy, as well as the protection of human health and the environment against ionizing radiation. In fulfilling this statutory objective, the Agency has emerged as a unique multidisciplinary organization in the United Nations system to address global challenges related to nuclear technology, including global energy security, human health, food security and safety, and water resource management, and to nuclear safety and security and non-proliferation

TECHNICAL COOPERATION SUPPORTING RADIATION SAFETY INFRASTRUCTURE IN MEMBER STATES

The Agency's statutory objective is to: "…seek to accelerate and enlarge the contribution of atomic energy to peace, health and prosperity throughout the world" and "…ensure, so far as it is able, that assistance provided by it or at its request or under its supervision or control is not used in such a way as to further any military purpose.". The overall objective of the Agency's TC programme is to enhance the contribution of nuclear technologies for sustainable development of the Member States, taking into account the specific needs of developing countries, including those of the least developed countries.

The Agency Member States benefited over decades from the technical cooperation programme to support the developments and strengthening radiation safety infrastructure. Since the 80's where only about 40 Member States received assistance through TC projects, the number increased to about 100 in the 90's and about 125 in the 2000's. During 2014 a total of 136 Member States received assistance. In 2013 the funds devoted to this assistance were 22,8 % of the total TC budget. It is important to mention the in kind-contribution extra-budgetary projects of developed Member States.

From 2005 to 2011 the infrastructure elements of the technical cooperation projects focused on occupational radiation protection were organized covering the following areas: Regulatory infrastructure for occupational radiation protection; Individual monitoring for external radiation sources; Individual monitoring for intake radionuclides; Workplace monitoring; Service providers; Implementation of the requirements by end users and occupational exposure to natural sources. As of 2012 the infrastructure elements were re-grouped to better reflect the development in the Member States and to target the end-users. Then the new structure covered: Technical and Scientific Organizations (TSO); Implementation of Radiation Protection programme in Medical Applications; Implementation of Radiation Protection programme in

Industrial Applications & NORM; Implementation of Radiation Protection programme in Production of Isotopes and Implementation of Radiation Protection programme in Nuclear Fuel Cycle.

Over last decade the Radiation Safety Information Management System- RASIMS was developed as a tool to jointly collect, analyse and view information regarding the national infrastructure for radiation safety. RASMS is a web-based platform that enables Member States and the IAEA Secretariat to keep up to date the info on national infrastructure, analyze the trends and identified needs and priorities. The information in the system is a clear evidence that there is a need to continue supporting the IAEA technical cooperation programme as key element for implementation of the radiation safety standards. New emerging technology in the medical sector, the promotion of safety culture and networking would be key elements to be consider for capacity building in the future within TC programme.

OCCUPATIONAL RADIATION PROTECTION APPRAISAL SERVICE- ORPAS PROCESS

As a tool to verify compliance with international standards related to occupational radiation protection, the Agency developed an appraisal services titled ORPAS. This service is implemented upon request of Member States. The main objectives of the appraisal service are:

- Provide the host country with an objective assessment of the provisions for occupational radiation protection.
- Identify the strengths in the host country which are unique and worthy of bringing to the attention of others.
- Promote the use of self-assessment by the host country.
- Identify areas where performance should be improved to meet international standards.
- Make recommendations on actions to be taken to achieve such improvements.

The ORPAS is making used of several questionnaires developed form the IAEA Basic Safety Standards and related Safety Guide and reports. An essential element of ORPAS is the pre-mission and the self-assessment as a routine and continuing process conducted by senior management and management at other levels in Member States. The self-assessment is basic to evaluate the effectiveness of performance in all areas of their responsibility. The Agency developed for this purposes SARIS, a collaboration platform (http://gnssn.iaea.org/CSN/SA) that contain modules for self-assessment of regulatory authorities as well as end-users.

Over last decade several OPRAS mission were organized in Latin America, Europe and Africa. Main finding and improvement possibilities are listed below for service providers and end-users.

For service providers, including personal dosimetry and workplace monitoring as well as calibration services the finding are summarizes as follows:

- Individual monitoring services is done by several institutions.
- Financial considerations are limiting the full coverage of the workers monitoring.
- There are no clear legal requirements for approval of technical services.
- Monitoring of external exposure limited for the whole body. No extremity nor lens of the eye monitoring is performed. Neutron monitoring is very limited.

- Conditions during the calibration comply with the relevant standards, ISO 4037-1, -2 and -3. Limited facilities.
- Facilities for monitoring of internal exposure very limited.
- There is a lack of Quality Management System.

For end-users, including application of ionizing radiation in medicine, research and industry the findings are as follows:

- There is a lack of appropriate and documented Radiation Protection Programme.
- Financial considerations are limiting the full coverage of the workers monitoring as well as limited workplace monitoring programme.
- Limited health surveillance programmes.
- There is a lack of optimization processes.
- There is a lack of Quality Management System.
- There is a lack of Radiation Protection Training programme. Aging of staff is a serious issue.
- There is a lack of Safety Culture applied to activities and facilities.
- There is a lack of proper Dose Registry at the facilities and at national level.

The improvements possibilities identified and being currently implemented in the framework of the national or regional technical cooperation project covering the occupational radiation protection. Few examples are:

A prototype of a National Dose Registry was developed. There is a need to disseminate the experience in Latin America in relation to he designed and deployed this prototype.

Many Member States are facing difficulties in promoting and maintaining a strong safety culture. This can only be achieved through effective training programme for all workers involved in the use of ionizing radiation and targeted awareness and sensitization programme to all relevant stakeholders. The Agency is working with the Ibero-American Foro of Regulators to complete a document on Safety Culture in Radiation Safety. This document would be the basis for capacity building in the region.

The Agency continues to promote the use of ORPAS for all Member States with the IRRS service already performed and thus with focus on the End-user and Technical Support Organization. It is necessary to continue promoting self-assessment tools as SARIS covering all operational aspects of radiation safety for end-users and TSO.

Several regional networks and forums exist in different regions, they have also contributed to strengthen the networking for a harmonized approach in the implementation of the requirements of the International Basic Safety Standards, by fostering experience sharing and identification of best practices for the efficient and effective implementation of these requirements. There is a clear need to continue promoting networking on optimization of protection as well as action on safety culture in organization, facilities and activities in radiation safety.

CONCLUSIONS

The IAEA, through its technical cooperation programme, has provided significant assistance for capacity building in all regions and will continue to do so under the limited resources available. The Agency continues supporting the IAEA technical cooperation programme as key element for implementation and further development of the radiation safety standards. Specifically, there is a commitment to continue promoting networking on optimization of protection as well as action on safety culture in organization, facilities and activities in radiation safety.

CHAIR'S SUMMARY OF ROUND TABLE 4 – CHALLENGES IN IMPLEMENTING OCCUPTIONAL RADIATION PROTECTION

Several presentations were made on the regional experiences in Latin America, Europe, Africa and Asia as well as two scientific societies. Despite the fact that much has been achieved under the different modalities of technical cooperation projects and other initiatives in each region, there were still a need to further strengthen the national systems in many Member States for the protection of health and safety of workers who are occupationally exposed to radiation to ensure compliance with the requirements of the IAEA International Basic Safety Standards. They are all facing various challenges to achieve this objective, and the most common ones are highlighted below:

IMPLEMENTATION OF RADIATION PROTECTION PROGRAMMES AT END-USER FACILITIES

The effective implementation of radiation protection programmes at the end-user facilities requires a strong and effective national radiation safety infrastructure, including the regulatory authorities, end-user themselves and all other stakeholders. Almost all the Member States do have a regulatory system in place, but in many countries the system is not fully effective. It is therefore essential to maintain the international co-operative efforts.

PROVISION OF A QUALITY DOSIMETRY AND MONITORING SERVICE

There are a limited number of dosimetry service providers in Member States. In many developing Member States, there is only one service provider, for external dosimetry and photon radiation. Another common challenge is to further develop capabilities for quality management in dosimetry service to also include extremity dosimetry and internal dosimetry. Regular inter-comparison exercise is important to improve and benchmark the quality of the dosimetry service.

DOSE RECORD MANAGEMENT OF OCCUPATIONAL RADIATION EXPOSURES.

Many Member States does not have an effective dose management system or national dose registries to manage the occupational exposures of workers. Some of them are basically using the Excel software to keep record of the occupational radiation doses, and some others are also trying to customize the Regulatory Authority Information System (RAIS) software developed by the IAEA to be used as a dose record management tool. There is a need to disseminate the experience in Latin America in relation to he designed and deployed prototype of National Dose Registry.

CAPACITY BUILDING

There is a lack of adequate human and financial resources in relation to occupational radiation protection. The IAEA, through its technical cooperation programme has provided significantly assistance for capacity building in all regions and will continuing doing so under the limited resources available.

PROMOTING AND MAINTAINING A STRONG SAFETY CULTURE

A strong safety culture is a key for a sustainable occupational radiation protection infrastructure. Many Member States are facing difficulties in maintaining a strong safety culture. This can only be achieved through effective training programmes for all workers involved in the use of ionizing radiation and targeted awareness and sensitization programmes to all relevant stakeholders.

APPRAISAL SERVICE AND SELF-ASSESSMENT.

It is very important to promote the use of ORPAS for all Member States with the IRRS service already performed and thus with focus on the End-user and Technical Support Organization.

NETWORKING

Several regional networks and forums exist in different regions. They have also contributed to strengthen the networking for a harmonized approach in the implementation of the requirements of the International Basic Safety Standards, by fostering experience sharing and identification of best practices for the efficient and effective implementation of these requirements. There are problems and difficulties with the self-sustainability of those networks. There is a clear need to continue promoting networking on optimization of protection as well as action on safety culture in organization, facilities and activities in radiation safety.

IRPA to provide a medium whereby those engaged in radiation protection activities in all countries may communicate more readily with each other and through this process advance radiation protection in many parts of the world.

SYNERGIES.

All stakeholders' involvement is essential for improving occupational radiation protection. Workers, trade unions and professional bodies are actively participating, together with employers.

It is essential to maintain and synergize the international co-operative efforts to meet the above challenges in implementing occupational radiation protection in Africa and to further strengthen the radiation safety infrastructure in the region.

To continue supporting the IAEA technical cooperation programme as key element for implementation of the radiation safety standards.

YOUNG PROFESSIONALS ROUND TABLE

Chairperson: M. Hajek, and A. Hefner, Austria

CONCLUSIONS OF THE YOUNG PROFESSIONALS' ROUNDTABLE

M. Hajek, A. Hefner**, +*

**International Atomic Energy Agency, Vienna, Austria*
***International Radiation Protection Association*
+Seibersdorf Laboratories, Seibersdorf, Austria

Ensuring competence in the field of occupational radiation protection requires education and encouragement of qualified professionals. In order to maximize the positive impact of international radiation protection activities, promotion of young scientists and professionals is considered of paramount importance.

The International Atomic Energy Agency (IAEA) encouraged young scientists and students of relevant disciplines, defined as those who have worked in the field of radiation protection for less than five years and are younger than 32 years of age, to attend the International Conference on Occupational Radiation Protection and take it as an opportunity to exchange information with experienced practitioners, gain knowledge and guidance and engage in networking with senior professionals. Involvement of young scientists at the level of conferences, professional societies and radiation protection committees is crucial, as it certainly is the young generation that will be most affected by the decisions made by these parties today.

The Young Professionals Roundtable was intended for newcomers to and young members of the radiation protection community to discuss their visions and ideas with a broad audience. Three candidates had been selected to represent the young scientists as panellists on the podium and give an introductory statement to trigger the discussion. Approximate equal geographic distribution was attempted to be achieved, with representatives from Africa, Europe and Latin America. The topics addressed in the key statements were the following:

- National and global networking of radiation protection young professionals;
- Education and training in developing countries; and
- Role of young professionals in international radiation protection committees.

The following objectives emerged to be those of most concern to the young professionals:

— Attracting young people

The professionals, who developed today's radiation protection framework and know-how worldwide, are starting to retire. More and more young people must be prepared to take on leadership positions in the radiation protection community. The young professionals identified the need for positive measures and actions to recruit and educate young people as scientists, engineers, technicians and skilled staff, emphasizing persisting scientific challenges and the attractivity of a career in the field of radiation protection. The need for education and training is particularly emerging in less developed countries.

— Opening up conferences

It has almost become sort of a tradition at international topical conferences to implement young scientist events, such as informal get-togethers to facilitate networking or competitive awards to highlight excellent research achievements. International organizations and, specifically, the International Radiation Protection Association (IRPA) were strongly requested to continue their role in fostering support of young scientists through integrating them in scientific programme committees. These opportunities were much appreciated and shall be a first step to verify that the voice of the young generation is heard and its interests are properly reflected in the radiation protection community.

— Preparing for leadership

In some professional societies and committees, the transition of leadership from the generation, which developed the current radiation protection concepts and principles, to the young generation is already taking place. The young professionals strongly support the exchange of knowledge between the elder and younger generation for mutual benefit. An interactive platform shall be created for integration of young professionals, which is mediated by senior practitioners.

— Thinking globally

Radiation protection is an international concern. Tomorrow's leaders shall have an international perspective and must know their colleagues in other countries. National and global networking of senior and young professionals is required to implement a safety culture, ethical practices and cope with the challenges of radiation protection in a global society.

CLOSING SESSION

Chairpersons

M. F. Weber

United States of America

M. L. Perrom

France

Statements are as provided, verbatim.

PRESIDENT'S SUMMARY OF THE CONFERENCE

M. Weber

US Nuclear Regulatory Commission

United States of America

Excellencies, distinguished colleagues, ladies and gentlemen. Thank you for joining us in this important conference devoted to the enhancement of occupational radiation protection. This second International Conference on Occupational Radiation Protection was hosted by the International Atomic Energy Agency (IAEA) and the International Labour Organization (ILO) here at the headquarters of the IAEA in Vienna, Austria, on 1 to 5 December 2014. We have come together, shared our insights and challenges, and exchanged information and experience. We have reviewed developments, advances, challenges, and opportunities. Now we are formulating conclusions and recommendations.

The conference assembled over 500 delegates from 96 Member States. Subject matter experts in radiation protection and associated specialties from around the world reviewed the status of occupational radiation protection with the objective of enhancing protection of workers. The IAEA has statutory responsibility to establish safety standards for protection against the negative effects attributable to radiation exposure, including such standards for occupational protection, and also to provide for the application of those standards. It has been establishing such standards, including the revised Radiation Protection and the Safety of Radiation Sources: International Basic Safety Standards (BSS) General Safety Requirement (GSR) – Part 3, for more than 50 years. The IAEA is also establishing a comparable suite of standards for security. In addition, IAEA has a major program for strengthening radiation protection infrastructure in over 82 countries. The ILO has overall responsibility for occupational safety and health, which it discharges in the radiation protection area mainly through Convention 115. This Convention has been ratified by, and has thus become binding on, 50 countries. The ILO is also a cosponsor of the BSS and other international radiation safety protection standards. The IAEA and ILO, in cooperation with Member States and the sponsoring organizations, professional societies, employers, and employees work together to ensure protection of workers from ionizing radiation.

The overall message in the opening of and throughout the conference was that countries and multilateral organizations are working together to enhance protection of workers. Occupational radiation protection over the past several decades is a success story for the international radiation protection community by protecting workers and reducing occupational exposures. This is especially true for protection of workers at nuclear installations around the world. As a result of local economic, social and political conditions, gaps and challenges remain where the picture is not as clear or compelling. Focused effort by multilateral organizations, Member States, licensees, operators, employers, and employees is required to close the gaps and overcome the challenges to enhance protection of workers. In addition, as the workforce ages and new workers begin working, transfer of knowledge of the highly successful radiation protection principles, framework, and tools is required to ensure that the high level of protection will continue long into the future.

CONFERENCE FINDINGS

At the beginning of the conference, we focused our collective attention on three essential questions:

- Who accomplishes occupational radiation protection today and in the future?
- What situations exist where application of the revised Basic Safety Standards in protecting workers is more challenging, such as mining, aviation, and advanced medical procedures?
- How can the international community best sustain and enhance occupational radiation protection?

Throughout the conference, we have heard a variety of answers to these questions. We appreciate your attention to these questions as we have probed and stretched to close the gaps and resolve the challenges in occupational radiation protection. Your answers have prompted ideas and recommendations on how we can and should enhance protection of workers by building on the momentum from this week's conference.

The standards for radiation protection developed at the international level are generally satisfactory as a framework for the control of occupational exposures in developed and in developing countries. Changes to the standards should only be made where necessary to reflect enhanced scientific understanding of the effects of ionizing radiation exposure or to fill gaps, improve clarity, facilitate application, or ensure the necessary level of protection. Unjustified changes can have unexpected and negative side effects and can undermine confidence in the radiation protection system, if not properly justified and clearly communicated. Continued attention to the development of the ethical basis for radiation protection will assist consistent application, and improve understanding and communication.

With respect to consideration of the recommendations of the International Commission on Radiological Protection (ICRP), as far as occupational exposures are concerned, further major modifications of the international standards do not appear necessary. The international safety framework for protecting workers is well established and effective, including application of the three fundamental principles of justification, optimization, and dose limitation. However, implementation of some of these recommendations in some areas, such as medicine and work involving exposure to elevated levels of naturally occurring radiation is complex.

Exposure to natural radiation is an inescapable feature of life. All workers are exposed to natural radiation whether they are working or not. When action is possible and justified, workers exposed to natural radiation should be given the same approach to protection, including optimization, as those exposed to radiation from artificial sources. Focus should be placed on workers receiving higher levels of exposure. Clearer international standards and guidance is needed to assist employers and regulatory authorities in applying a graded approach of protection, including applications to radon and progeny.

In industrial and research facilities, occupational doses are generally quite acceptable. There are, however, specific industrial and research facilities that involve higher routine exposures and occasional accidents with significant exposure consequences. A primary example is industrial radiography, which is performed in difficult environments by individual workers and where safety relies largely on adherence to procedures and human performance. High occupational exposures associated with accidents may be caused by a failure to follow procedures and appropriate monitoring, including the use of alarming dosimeters and other radiation monitoring. Improved worker training, improved safety culture, practical ways to optimize exposure in the wide variety of working environments, and sharing of operating experience could enhance worker protection for these facilities and applications. For example, an effective model for such sharing is the Information System on Occupational Exposure that is used to share dose reduction information and operational experience to improve the optimization of worker radiological protection at nuclear power plants.

Exposures of workers in the practice of medicine, including the use of conventional radiology for diagnosis and therapy, are generally well controlled and in accordance with international safety standards. There are, however, new and emerging medical practices, especially interventional radiology and interventional cardiology, in which higher occupational exposures are occurring. These exposures to both workers and patients are growing as the procedures are being used with increasing frequency. There is broad recognition that actions taken to protect patients from unnecessary radiation exposure also contribute to protecting workers. The contributions of medical physicists have also succeeded in reducing worker and patient exposures. Sufficient attention should be paid to the optimization and control of these exposures, through design (e.g., shielding) and conduct of the procedures, monitoring of exposures, improving safety culture and awareness of best practices and optimization, and improved training and education of the medical professionals, including physicians, nurses, and other workers who contribute to successful health outcomes and occupational radiation protection.

Radiation protection should be an integral part of the general health and safety protection of workers and of safety regulation and management systems in the workplace. Workers may face a wide range of occupational hazards and unduly protecting workers against one or a few hazards may be detrimental to occupational safety and health, if such protection undermines protection against other comparable or greater workplace hazards. Radiation hazards are just one type of hazard to which workers are exposed, and these hazards may be more or less significant than other occupational hazards. In some settings, radiation protection may be of secondary or tertiary importance. Therefore, application of radiation protection measures, including application of optimization, must be examined within the context of the totality of workplace hazards, thereby using resources to achieve the greatest gain in worker protection. A more holistic approach is needed that recognizes and appropriately protects against this large range of hazards. In addition, although social and economic factors are taken into consideration in applying the optimization principle, there should be no fundamental difference in standards of protection between developed and developing countries. For the sake of worker protection and credibility, international standards must be applied uniformly and effectively. Operating experience in protecting workers must also be shared and used to make appropriate revisions to the standards and facilitate their effective application.

CALL FOR ACTION

Based on the first conference in Geneva in 2002, 14 action items were identified and each of them has been successfully accomplished during the intervening years. Similarly, the 2014 Vienna conference identified a number of desirable actions to enhance protection of workers, including:

1. Enhancing training and education in occupational radiation protection to equip workers with the necessary knowledge, skills, and competencies to accomplish worker protection, including periodic refresher training in radiation protection and practical measures to reduce exposures.
2. Improving safety culture among workers who are exposed to ionizing radiation, including promotion of safety culture by regulatory authorities through outreach and education.
3. Developing young professionals in radiation protection particularly for developing nations, through communication, networking, training, research, hands on experience, and participation in technical meetings and conferences.
4. Implementing the existing international safety standards to enhance occupational protection of workers, including assisting Member States in facilitating implementation and encouraging a holistic approach for worker protection.
5. Developing and implementing new international safety guides for occupational radiation protection in different exposure situations, including advanced accelerator facilities and interventional radiology.
6. Promoting exchange of operating experience, particularly for industrial radiography and medical radiology and including appropriate consideration of human factors, not just among Member States and regulatory authorities, but also among operators, radiation protection officers, and vendors.
7. Convening an appropriate international forum to exchange additional information and analysis of worker protection in different exposure situations, including during nuclear emergencies to identify lessons and implement plans for the protection of workers and helpers, enhance worker preparedness, guide the rapid transition from planned exposure to emergency response, and improve radiation protection in emergencies.
8. Applying the graded approach of the BSS in protecting workers against exposures to elevated levels of naturally occurring radiation or radioactive materials, including flight crews, miners, and other workers.
9. Enhancing assistance to Member States with less developed programs for occupational radiation protection to support practical implementation of international safety standards.

It has been 12 years since the first international conference on occupational radiation protection. The experience gained during this interim period has been valuable and confirmed the successful application of the safety framework for protecting workers from ionizing radiation. This is a success story for worker protection. We now need to build upon this success to ensure a broader range of workers achieve comparable protection. We should not wait as long before we convene the third conference on occupational radiation protection. Implementation of the latest ICRP recommendations and the revised BSS may present new and unforeseen gaps and challenges during the next several years. In light of this dynamic environment, it could be timely to conduct this third conference in about five years from the present.

CLOSING ADDRESS

P.S. Hahn

Director, Division of Radiation, Transport and Waste Safety

International Atomic Energy Agency

Austria

Mr President, colleagues and friends,

Let me begin by thanking you, Mr Michael, for your stewardship of our conference and for the excellent summary you have just provided. This will help us to plan what we need to do next, both here in the Agency and in the Member States.

I know that there have been many interesting and useful presentations this week. Many people have commented that a lot of good work has been done in the area of occupational radiation protection since the first Conference in 2002, and that the presentations demonstrated good practical activities and experience. New international requirements on occupational radiation protection, such as the new limits on eye-lens, and the accident at TEPCO's Fukushima Daiichi Nuclear Power Station have posed big challenges in improving and ensuring the occupational radiation protection.

I believe many good experiences have been shared and valuable recommendations provided both in presentation session and discussion session, among which the most important is the fully implementation of revised Radiation Protection and Safety of Radiation Sources: International Basic Safety Standards (BSS), IAEA safety standards series No. GSR Part 3, on the basis of the specific conditions of each Member States. As the director of Division of Radiation, Transport and Waste Safety in the IAEA it is pleasing to have seen so many examples of the BSS and other IAEA Safety Standards being implemented by Member States across all of the elements of occupational radiation protection. It is even more pleasing to see how the Member States have adapted the guidance to meet their own national needs including, for example activities in: workplace and individual monitoring; training and qualification of workers; dose record and assessment; optimization of radiation protection in each practice. I believe the experiences shared and recommendations provided during this week will further improve our work in this important area.

I would also like to take this opportunity to thank our exhibitors who added to the conference experience. Finally, I would like to thank our own staff for organizing this event and ensuring it ran so smoothly.

Ladies and Gentlemen, you have had a week and have participated actively and I am sure you are all looking forward to getting back to your respective homes so I thank you once again for your participation and wish you all a safe journey home.

Thank you.

Annex

SUPPLEMENTARY FILES

The supplementary files for this publication can be found on the publication's individual web page at www.iaea.org/publications.

LIST OF CHAIRPERSONS AND PARTICIPANTS

CHAIRPERSONS OF SESSIONS

Opening Session	M. PINAK	IAEA
	P.S. HAHN	IAEA
Briefing Session	M. F. WEBER	United States of America
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No. 26

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