OCCUPATIONAL RADIATION PROTECTION:

PROTECTING WORKERS AGAINST EXPOSURE TO IONIZING RADIATION

Proceedings of an International Conference, Geneva, 26–30 August 2002

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FOREWORD

Occupational exposure to ionizing radiation can occur in a range of industries, in mining and milling, in medical institutions, in educational and research establishments and in nuclear fuel cycle facilities. The term ‘occupational exposure’ refers to the radiation exposure incurred by a worker which is attributable to the worker’s occupation and received or committed during a period of work.

According to the latest (2000) Report of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), an estimated 11 million workers worldwide are monitored for exposure to ionizing radiation. They incur radiation doses which range from a small fraction of the global average background exposure to natural radiation up to several times that value.

The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), which are co-sponsored by, amongst others, the IAEA, the International Labour Organization (ILO), the OECD Nuclear Energy Agency (OECD/NEA) and the World Health Organization (WHO), establish a system of radiation protection of which the provisions for occupational exposure are a substantial component. Guidance supporting the requirements of the BSS for occupational protection is provided in three Safety Guides, jointly sponsored by the IAEA and the ILO, and describing, for example, the implications for employers in discharging their main responsibilities (such as setting up appropriate radiation protection programmes) and similarly for workers (such as properly using the radiation monitoring devices provided to them).

It should be noted, however, that radiation protection is only one factor that must be addressed in order to protect the worker’s overall health and safety. The occupational radiation protection programme should be established and managed in co-ordination with other health and safety disciplines.

Less than half of the occupationally exposed workers are exposed to artificial radiation sources. The majority of occupationally exposed workers are exposed to elevated levels of natural radionuclides. Notably, those workers comprising this latter group receive a higher average annual dose than do those workers exposed to artificial sources. The principal natural sources of radiation exposure, other than the mining and processing of uranium ores, are radon in buildings, non-uranium or thorium ores that contain significant traces of natural radionuclides, other underground workplaces and cosmic rays at aircraft altitudes. The BSS provide for the exclusion of exposures, the magnitude or likelihood of which is essentially unamenable to control.

In order to address these issues the first International Conference on Occupational Radiation Protection, hosted by the Government of Switzerland, was organized by the IAEA and convened jointly with the ILO. It was co-sponsored by the European Commission (EC) and held in co-operation with the WHO and the OECD/NEA and also with UNSCEAR, the International Commission on Radiological Protection, the International Commission on Radiation Units and Measurements, the International Electrotechnical Commission, the International Radiation Protection Association and the International Society of Radiology. It was held at the Headquarters of the ILO, Geneva, from 26 to 30 August 2002, and attended by 328 participants from 72 countries and 12 organizations. Through the strong support of the IAEA's Technical Co-operation Department, and also from the EC, almost half of the participants were representing developing countries.

The Conference is the first international conference to cover the whole area of occupational radiation protection, including infrastructure development, radiation monitoring, stakeholder involvement, and the probability of causation of occupational harm attributable to radiation exposure. The Proceedings contain all the presentations and discussions as well as summaries of each session and the findings and recommendations of the Conference. The contributed papers are provided on a CD-ROM, which accompanies these Proceedings.

The IAEA gratefully acknowledges the co-operation and support of all the organizations and individuals that have contributed to the success of this Conference, and in particular the assistance given by the Government of Switzerland.

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EXECUTIVE SUMMARY

FINDINGS AND RECOMMENDATIONS OF THE INTERNATIONAL CONFERENCE ON OCCUPATIONAL RADIATION PROTECTION: PROTECTING WORKERS AGAINST EXPOSURE TO IONIZING RADIATION

This first International Conference on Occupational Radiation Protection, hosted by the Government of Switzerland, was organized by the International Atomic Energy Agency (IAEA), which convened it jointly with the International Labour Organization (ILO). It was co-sponsored by the European Commission (EC) and held in co-operation with: the World Health Organization (WHO), the OECD Nuclear Energy Agency (OECD/NEA), the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the International Commission on Radiological Protection (ICRP), the International Commission on Radiation Units and Measurements (ICRU), the International Electrotechnical Commission (IEC), the International Radiation Protection Association (IRPA) and the International Society of Radiology (ISR). It was held at the Headquarters of the ILO, Geneva, from 26 to 30 August 2002.

With so many organizations involved in the field of occupational radiation protection, it proved useful to clarify, in a briefing session, their interlocking responsibilities. The ILO has an overall responsibility for occupational safety and health which it discharges in the radiation protection context mainly through the promotion of Convention 115, which has been ratified by, and has thus become binding on, 47 countries. The ILO is also a co-sponsor of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) and of other international radiation safety related standards. The IAEA has a statutory responsibility to establish standards of safety for protection against the negative effects attributable to radiation exposure, including such standards for labour conditions, and also to provide for the application of those standards. It has been establishing such standards, which have included the BSS, for more than 40 years. The standards are now at three levels: fundamentals, requirements and guides. In addition, it has a major programme for strengthening radiation protection infrastructure which now covers 82 countries. The EC also has competence in radiation protection, through the 1957 Euratom Treaty, and issues basic safety standards through Directives that are binding on the Member States of the European Union. The WHO is a directing and co-ordinating authority on international health within the United Nations (UN) system. Under its mandate, and in collaboration with other UN bodies and with non-governmental organizations (NGOs), the WHO conducts health risk assessments of radiation exposure, promotes research and provides advice to national authorities. The OECD/NEA, although a co-sponsor of the BSS, does not issue standards but concentrates on building consensus in the development of international recommendations, and it operates the Information

System on Occupational Exposure (ISOE) jointly with the IAEA. Another important organization is UNSCEAR, which estimates the levels and effects of radiation exposure for the United Nations General Assembly and thereby establishes the scientific basis for standards for the entire UN system. The ICRP is an NGO whose recommendations have been the basis for all the standards issued by the organizations mentioned earlier, and together with its sister organization, the ICRU, it has developed definitions of quantities and units for basic and operational measurements. Professional societies are also important in this area and both the IRPA and the ISR co-operated in the Conference.

The overall message to come from the opening presentations was that, in general terms, occupational radiation protection over the past few decades has been a success story for the international radiation protection community. Global information from UNSCEAR and the ISOE, supported by many detailed national studies, has revealed solid positive trends in many key performance indicators, primary among which are the annual average dose and the annual collective dose, but also indicators such as the number of workers exposed to high doses and the number of accidents and overexposures. It is worth noting, however, that most of these data relate to the nuclear fuel cycle; 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 incurred globally.

1. CONFERENCE FINDINGS

On the topic of standards for radiation protection, the feeling was that the standards developed at the international level now in place are generally satisfactory as a framework for the control of occupational exposures in developed and developing countries. Changes to the standards should not be made for their own sake but only to fill gaps, to improve clarity, to facilitate application and to improve protection. It was noted that changes can often have unexpected side effects and can lead to lack of confidence in the radiation protection system.

With particular reference to the current consideration by the ICRP of a revision of its recommendations and so far as occupational exposures are concerned, major modifications do not seem necessary. However, some problems should be addressed. A worldwide agreed standard for restricting individual radiation doses is essential, be it called ‘dose limit’ or ‘action level’, but optimization is the main tool for efficient dose reduction and could be strengthened by defining case specific dose targets or reference dose levels. The management of occupational exposure to natural radiation deserves careful attention in the future system. Terminology, especially the definitions of ‘risk’ and ‘detriment’, should be clarified.

Risks to workers from typical levels of rates of exposure to radiation of a few millisieverts per year are comparable to those from exposures to other hazardous substances (including carcinogens) in the workplace and, due account being taken of differences in life shortening impact, to other hazards at work. Continuous exposures near the dose limit would, however, involve risks comparable to those in recognized high risk occupations. These circumstances justify the attention being paid to the management of higher individual doses, but do not mean that attention to routine dose levels can be relaxed. It is also relevant that there is a general downward trend in exposures to other hazards. In this respect, the continued use and expansion of international mechanisms for facilitating application of the fundamental principle of optimization of occupational radiation protection (i.e. that such protection should be the best under the prevailing circumstances) — for example, ALARA[1] networks — should be encouraged.

Exposures of workers in conventional radiology, both radiodiagnosis and radiotherapy, are generally well controlled. There are, however, new areas of medical practice, especially interventional radiology, in which very high exposures are incurred. Ensuring that sufficient attention is paid to the control and reduction of such exposures requires continued efforts in post-graduate education and in awareness raising of the medical professionals involved. The participation of health physicists in the implementation of optimization programmes in interventional radiology is strongly recommended.

Natural radiation is an inescapable feature of life on earth to which everyone is exposed while at work. It is necessary, therefore, to decide which exposures to natural radiation need to be considered from a radiation protection viewpoint by defining what exposures are amenable to control by the employer. Once this has been decided, workers exposed to natural radiation should be given the same level of protection (optimized) as those exposed to artificial radiation. As with artificial radiation, the focus should be on those exposed to the higher levels. Clearer guidance is needed to assist regulatory authorities in deciding what activities to regulate and how to apply a suitable graded approach to regulation, and here a clear international definition of 'radioactive substance' is needed.

In industrial and research facilities, the average occupational doses are generally quite acceptable. There are, however, specific types of work that involve both high routine exposures and a number of accidents; pre-eminent among these is industrial radiography, which is often carried out in difficult environments by unsupervised workers and where safety relies largely on procedures and human

[1] ALARA is an acronym for the ICRP recommendation on the optimization of radiation protection, namely, that radiation doses be kept 'as low as reasonably achievable', social and economic considerations being taken into account.

performance. Analyses of accidents have identified the major cause as failure to follow procedures, especially with regard to the use of alarm dosimeters and source position monitors. This has been known for many years, but the message is not getting across to the persons responsible. Some key factors that might improve the situation are: the targeting of regulatory pressures, more involvement on the part of qualified experts (see the relevant requirement in the BSS), appropriate and continuing training of operators, and wide availability of information on accidents and lessons learned. As regards the last mentioned factor, the completion and improved availability of publications and databases such as the Radiation Events Database are strongly encouraged.

Occupational radiation protection in the nuclear fuel cycle has received more attention than occupational radiation protection in any other practice. The main driving force for occupational exposure control has been application of the optimization (ALARA) principle, which is now part of normal job planning and almost second nature. The results over the past few decades in terms of reductions of all indicators — average doses, collective doses per unit energy generated and numbers of people receiving high individual doses — are well documented. International databases and mechanisms such as the ISOE and ALARA networks are very important in maintaining this situation. Concern is still warranted over the control of exposures of itinerant workers and contractors. They are subject to divided responsibilities as between employers and licensees, and may even work across national boundaries. It was noted that there is a move towards more personal control of workers over their own working arrangements, including radiation protection, facilitated by personal alarm dosimeters. Both of these aspects make the inculcation of optimization or ALARA awareness at the individual level even more important. It may be ‘eye catching’ to add it to the three traditional protection considerations so that they become ‘time, distance, shielding and awareness’. More emphasis should also be given to the aspect of optimization relating to the prevention of accidents. A potential problem may arise because of the delays in decommissioning, which will result in loss of direct knowledge of facilities. Demonstration of compliance with international standards could be facilitated by international guidance on what represents good compliance in the nuclear industry, and indeed in other industries.

The decreases in average and collective doses may not be sustainable in the face of changes in work requirements, especially those associated with the termination of practices currently being performed, with the decommissioning of facilities and with end of life provisions. Note should be taken of the increasing age of workers in many areas and of the need to manage the generation change through the recruitment and training of younger workers.

Radiation protection should be seen as an integral part of general health and safety regulation and management systems in the workplace.

There should be no difference in standards of protection between developed and developing countries. Differences could impose higher occupational risks on populations already subject to high risks and allow promoters of practices to relax protection. In addition, for the sake of credibility, international standards must be applied uniformly.

The principle of the optimization of protection (ALARA) is the cornerstone of radiation protection in the workplace. It is important to recall that it relates not only to engineering or physical protection measures, but also to aspects such as safety organization and management, safety culture and safety training, many of which are associated with minimal costs and improvements in other areas — a ‘win–win’ optimization. It is not in line with optimization to devote substantial resources to the reduction of small risks. In this respect, occupational doses below 1–2 mSv/a may not warrant regulatory scrutiny. As optimization necessarily involves social and economic factors, its objectives are related to local circumstances.

There remain problems in both the formulation and the application of standards for the protection of pregnant workers and the embryo and foetus. International attention to this very important practical area is needed.

Dosimetry for monitoring occupational radiation doses from external X and gamma radiations is well developed thanks, to a considerable extent, to international intercomparison programmes. There are still technical difficulties in neutron dosimetry, but these have been under study for some time. In the monitoring of internal contamination dosimetry, some difficulties could be overcome if laboratories concentrated on estimating intakes, as required by standards, using internationally agreed protocols to then estimate committed doses.

Because scientific advances can be rapid, even though changes in the scientific consensus may evolve more slowly, it is important that regulatory structures for occupational radiation protection be able to respond. Often, political procedures and changes in primary legislation are very slow, so primary legislation should be ‘enabling’ rather than numerically detailed.

The regulatory authority for occupational radiation protection should be effectively independent. This means that it should be adequately staffed and funded, have the necessary knowledge and autonomy to take regulatory decisions and not be subject to inappropriate influence from any side, particularly promoters and politicians. Nonetheless, the regulator may need to become involved with employers and workers in developing solutions to radiation protection problems.

There should be more and better involvement of stakeholders[2], including workers, employers, regulators and professionals, in arriving at occupational

[2] The term stakeholder is used to mean all parties interested in occupational radiation protection.

radiation protection decisions and in their implementation in the workplace. In some cases, stakeholders, especially workers, may require training and assistance so as to be able to play the role that corresponds to their importance. Mechanisms for assessing stakeholder satisfaction should be developed and used. Stakeholders' problems of understanding are exacerbated by the complexity of the terminology and by terminological differences among different organizations, conventions, standards, etc.

For nuclear power plants, the ISOE is a very useful mechanism for disseminating information, examples of good practice and lessons learned. There are no similar mechanisms in other areas and it would be helpful to develop complementary systems.

A substantial proportion of all occupationally exposed workers will develop diseases similar to those developed by members of the general public, including cancers. The vast majority of these diseases will not be attributable to radiation exposure at work and some mechanism to decide on attribution is essential. In several countries, mechanisms using probability of causation schemes based on dose records and agreed risk factors are in use. These schemes, which need to be agreed between employers and workers, can provide for rapid and appropriate compensation to workers or their dependants. At present they are piecemeal, often not covering all the workers even in countries where they are operating. International guidance on the formulation and application of probability of causation schemes is clearly needed. Dose reconstruction is an essential component of compensation schemes, which must address the problem of uncertainty regarding doses and must be evidence based. The international organizations need to continue discussions directed towards the preparation of guidelines for assisting countries that are interested in establishing compensation schemes, in the establishment of which stakeholder involvement is highly desirable. The international organizations also need to encourage international co-operation in epidemiological studies of workers.

2. CONFERENCE RECOMMENDATIONS

In the light of the above findings, a number of specific recommendations for action emerged from the Conference. They are as follows:

(a) The international organizations should avoid unnecessary changes in standards of occupational radiation protection, so that regulatory stability can be maintained and implementation carried through.

(b) The international organizations should harmonize and, if possible, simplify their terminologies and their interpretations of requirements, especially those set out in conventions (including ILO Convention 115) and standards. Given the statutory responsibilities and the long tradition of the IAEA in the relevant field, this organization may wish to take the lead in an international harmonization effort. As part of this effort, the internationally recommended quantities and units should be used worldwide.

(c) To achieve the goal of better integrating radiation protection with general health and safety, the IAEA, with its specific radiation safety remit, and the ILO, with its overall worker safety remit, should consider collaborating more closely, especially in establishing and strengthening occupational radiation protection in developing countries.

(d) To achieve better dissemination of information and lessons learned into the medical, industrial and mining areas, the international organizations should consider whether systems similar to that of the ISOE could be established for these areas.

(e) The international organizations should consider producing a package of information and training materials designed to enable workers to participate fully as stakeholders in all aspects of radiation protection.

(f) The international organizations are encouraged to make widely available in appropriate forms, including via the internet and in local languages, analyses of lessons learned from accidents in industry to increase awareness and encourage responsible and safety conscious behaviour among management and workers.

(g) The IAEA should initiate the formulation of detailed practical guidance to assist regulators in deciding what occupational exposures are unamenable to control. This guidance should be incorporated into recommendations for establishing which industries involving exposures to natural sources of radiation should be subject to control as practices, including advice on graded approaches to regulatory requirements that are nonetheless compatible with protection from artificial sources.

(h) The international organizations should develop guidance on the formulation and application of probability of causation schemes for the compensation of workers for radiation induced occupational diseases.

(i) Many of these recommendations, and also a number of measures to strengthen occupational radiation protection globally, could be implemented if the international organizations, especially the IAEA and the ILO, formulated and implemented an international action plan for occupational radiation protection.

BRIEFING SESSION

STAKEHOLDER INVOLVEMENT

Chairperson's Summary
*W. Bines**
United Kingdom

(a) Radiation protection professionals:
   (i) Not a truly separate tier of stakeholder as they will generally always be either a regulator, an employer or a worker.
   (ii) The International Radiation Protection Association's role in the standards setting process should continue to increase, both by co-ordinating (and transmitting) the views of societies and by promptly sharing information with them.
   (iii) Further development of standards should consider the 'real world' and only address matters where improvement in protection is really necessary.

(b) Workers:
   (i) Particularly envisaged problems with the increasing contractorization in the nuclear industry.
   (ii) Need for more manager training, to put radiation protection within the wider context of health and safety issues rather than treating it as a separate issue.
   (iii) Interests of workers outside the nuclear industry should not be overlooked.

(c) Employers:
   (i) Need for greater stakeholder involvement in interpreting international standards to ensure a genuinely harmonized approach both between different countries and different industries.
   (ii) Legislation should define minimum 'safe' parameters, agreed globally.
   (iii) Need for agreed practical guidance (preferably also global) on issues that would 'make a difference'.
   (iv) Stakeholders should then agree locally any additional efforts that were justified in the particular circumstances.

(d) Regulators:
   (i) Offered an excellent case study with 'lessons learnt';
   (ii) Identified differing needs of developed and developing countries, particularly in respect of the role of the regulator;
   (iii) Need to check stakeholder satisfaction with the process;
   (iv) Identified need for workers to be trained, to give them the technical knowledge to enable proper involvement.

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* Summary provided on behalf of J. Takala.

TOPICAL SESSION 1

RADIATION RISKS IN THE WORKPLACE IN PERSPECTIVE

Chairperson's Summary
Ziqiang Pan
China

Current radiation protection programmes are major efforts which have been effective, overall, in reducing occupational radiation exposures. These reductions result from better control of human-made sources, optimization of practices and justification of exposures. Where increases in the use of radiation technologies have occurred, more workers are being monitored, with attendant increases in collective dose. To fully understand global trends in the radiation exposure of workers, several parameters should be used to describe exposure distributions including information on average doses, numbers of workers exposed, percentage of workers exceeding various levels of dose, and estimates of collective dose for the exposed populations. Regulations exist in most countries that result in worker protection through adoption of exposure limits consistent with the International Commission on Radiological Protection recommendations, optimization of work practices and justification of exposures.

To assess the successes of past radiation protection programmes and the need for changes in occupational radiation protection levels, radiation risks were compared with risks from other occupational hazards. Using average annual probability of death from occupational exposure in medicine and in the nuclear fuel cycle, risks from average exposures are similar in magnitude to risks from exposure to other known or suspected carcinogens. However, concerns persist for workers with higher potential exposures such as itinerant workers as well as for those exposed to natural sources of radiation, especially during underground operations such as mining. When workers are exposed to ionizing radiation at levels closer to the current exposure limits, risks of death are greater than in most sectors of the economy. These comparisons are highly dependent on the assumptions and comparisons made. For example, use of years of life lost instead of probability of death or incidence rather than mortality can lead to different conclusions. Nevertheless, such comparisons are informative in gauging the adequacy of radiation protection limits.

Better protection of workers can be achieved through the development of a common radiological and non-radiological risk management culture. To accomplish this education must begin in schools and continue in didactic programmes with workers, management, regulators, the media and the general public. In order for the risk management principles to be widely accepted, it is necessary to involve all stakeholders in a decision making process that is completely transparent.

In developing countries, the allocation of resources for radiation protection should be considered within the cultural, economic and social context. Primary prevention of health effects should receive higher priority than secondary medical screening with early intervention and tertiary treatment of preventable diseases.

Much of the success of occupational radiation protection programmes can be attributed to the historical focus on instituting controls on work with the greatest exposure potential. This principle should guide the profession as it faces future issues. The important issues in the future identified at this Conference include:

(a) The relatively undocumented exposure (and even the number of workers potentially exposed), of underground workers where natural sources of ionizing radiation are present and where radiation protection principles of optimization and justification are not usually applied;
(b) Transient workers who are likely to be increasingly involved in the decommissioning of nuclear facilities in the foreseeable future;
(c) The increasing applications of radiation technologies in nations with inadequate resources to address numerous public health needs.

Addressing these important issues requires:

(a) Better exposure assessment data for underground exposures to ionizing radiation which include average doses, numbers of workers exposed, percentage of workers exceeding various levels of dose and estimates of collective dose for the exposed populations;
(b) Operational and design targets based on as low as reasonably achievable principles particularly for the increasing numbers of workers involved in the decommissioning of nuclear facilities;
(c) Assistance to developing nations to enable them to build radiation protection infrastructures with due regard to other public health needs that these countries are facing.

Finally, the radiation protection profession should establish and maintain links with other risk management organizations. Through these links, the profession may learn about effective strategies for improved worker health while promoting a common risk management culture that results in better control of overall risks from occupational exposures.

TOPICAL SESSION 2

INFRASTRUCTURE DEVELOPMENT

Chairperson's Summary
C. Schandorf
Ghana

Topical Session 2 included a keynote address by R.H. Taylor, Head of Environmental and Safety Policy and Strategy, British Nuclear Fuels Limited, and member of the International Nuclear Safety Advisory Group (INSAG). His address was entitled Cultural and Organizational Issues Underpinning Radiological Protection.

Various authors contributed 24 papers in Topical Session 2 — Infrastructure Development. The papers were summarized by the rapporteur, S. van der Woude of the National Nuclear Regulator of South Africa.

The keynote address focuses on facility level infrastructure and discusses the cultural and organizational pre-requisites for developing and maintaining a good safety culture in operating organizations. The paper draws heavily on concepts taken from INSAG publications. Organizations with a strong safety culture have an effective safety management system, one which encourages total commitment, involvement, support and ownership of protection and safety at all levels of the organization.

The general framework for operational safety as proposed by INSAG-13 consists of the following essential elements:

(a) Definition of safety requirements and organizational safety goals;
(b) Planning, control and support;
(c) Implementation;
(d) Audit, review and feedback from operating experience.

To ensure an efficient safety management system it is necessary to develop an assessment plan to assess the integrity of the system.

R.H. Taylor indicates that when management is able to get everybody 'on board', with a clear understanding of requirements, corporate goals for protection and safety, and when individual and collective commitments to achieving and sustaining safety improvement are established, then a learning organization has been created with a self-sustaining safety culture.

With regard to managing change, R.H. Taylor draws attention to the need to review and assess the impact of technical and organizational changes affecting safety before embarking on such change. Organizational capacity to manage this change must also be considered in order not to undermine the already existing safety status of the organization.

INSAG has recently addressed the need for independence in regulatory decision making and a report on this will be published.

From the keynote and rapporteur presentations, several issues were raised as discussion points and the following key issues were discussed.

1. DEVELOPMENT OF NATIONAL INFRASTRUCTURE AND THE ROLE OF THE REGULATORY AUTHORITY

Infrastructure is the term used to describe the basic organization and management required to discharge the functions related to protection and safety. A national level infrastructure as well as a facility level infrastructure should be developed, commensurate with the number and complexity of practices, plants and installations in a given country.

On the issue of the independence of the regulatory authority, the focus should be on effective independence to make decisions and to control actions related to protection and safety, not necessarily administrative independence. It was emphasized that attributes of knowledge, competence, transparency, trustworthiness and the existence of good relations between the regulatory authority and its staff are critical to the establishment of effective independence. Establishment of independence is an evolutionary process and the focus should be on radiation protection and safety, not on bureaucratic authority. The IAEA should emphasize this in its guidance documents and expert missions. The challenges to effective independence are inadequate funding of the regulatory authority and limited numbers of adequately trained and motivated personnel.

It was accepted that basic education, training and working experience are essential to competence building in radiation protection and safety for regulators, operators and service providers. Mechanisms to enhance the effectiveness should be considered, namely, short, focused, practically oriented courses/workshops, fellowships, distance learning through the internet and standardization of training materials so that there is uniformity of competency and performance.

IAEA efforts in these areas should be upgraded and strengthened.

2. SAFETY CULTURE

Safety culture in an institution has two levels, namely, the corporate level and the individual level. The three stages of developing and maintaining safety culture should be used to strengthen individual and corporate safety cultures:

(1) Safety should be governed by compliance with, and adherence to, externally imposed rules and regulations imposed by the regulatory authority.
(2) Good safety performance should be based upon achieving well-established organizational safety targets and goals.
(3) Safety should be accepted as being not an event but a continuing process of safety improvement to which everyone in the organization should be given the opportunity to contribute.

Everyone in the organization, including management, should have a strong attitude towards, and place a high priority on, safety.

On the issue of quantifying safety culture, it was pointed out that it is not an easy task since factors to be considered are complex. However, INSAG-15 provides some guidance on approaches as well as recommended questions to be asked. One may consider using a similar safety climate assessment to that applied in other disciplines. The implementation and evaluation of safety culture in occupational radiation protection requires more attention in IAEA guidance documents, training and expert missions.

3. COMMUNICATION OF RISK

It was accepted that communication of risk by radiation protection professionals and regulators to the public is generally unsatisfactory. There is the need to develop proficiency in using plain language to communicate radiation protection concepts and principles, safety culture and risk estimates to decision makers, workers, the media and the general public in order to have full participatory involvement on issues of protection and safety.

4. MANAGEMENT OF CHANGE

Analysis of the age structure of regulators, operators and service providers indicates that there is a high probability of loss of corporate memory as regards very knowledgeable and experienced personnel. Concern was expressed about this trend.

Strategies for promoting capacity building for the younger generation of regulators, operators and supporting service organizations have to be addressed to ensure sustainability and continuity of performance.

5. ISSUES OF FUTURE CONCERN

5.1. Infrastructure development at facility level

The IAEA has provided guidance in IAEA-TECDOC-1067 on Organization and Implementation of a National Regulatory Infrastructure Governing Protection Against Ionizing Radiation and the Safety of Radiation Sources, which covers the essential elements of safety infrastructure at the national level required to apply the International Basic Safety Standards to radiation sources used in medicine, agriculture, research, industry and education. It also provides guidance on approaches to the organization and operation of the infrastructure aimed at achieving its maximum efficiency.

There is the need to develop a similar practical document for infrastructure at the facility level in the immediate future.

5.2. Guidance on communication of risk

The IAEA, in collaboration with the appropriate experts, should consider developing guidance on the communication of risk to all stakeholders involved in issues of protection and safety. A starting point could be to consolidate lessons learnt in different countries.

5.3. Harmonization of radiation protection and safety and operational safety and health infrastructure development

The IAEA, the International Labour Organization and the World Health Organization should spearhead an initiative to harmonize radation protection and safety and promote occupational safety and health infrastructure development.

TOPICAL SESSION 3

STATUS OF OPERATIONAL IMPLEMENTATION OF BASIC SAFETY STANDARDS

Chairperson's Summary

Z. Prouza
Czech Republic

Close collaboration at international and multilateral levels is necessary for establishing or improving national radiation protection infrastructures. In this regard, the IAEA model project is a good example of international co-operation for strengthening radiation safety infrastructures. The degree of active involvement of Member States and the progress achieved in the implementation of the International Basic Safety Standards (BSS) were analysed. The conclusion regarding model project implementation was that it was good, but there was still some way to go. The desirability of assessing the situation in the non-Member States of the IAEA, for which there is very little information, was emphasized.

The conclusion from a number of presentations, and reinforced in the discussion, is that in several countries the improvement of legislation, radiation protection standards and services requires:

(a) An adequate scheme for classification of sources, including natural and artificial sources.
(b) The identification of potentially hazardous practices by assembling information on the behaviour of relevant radionuclides in the processing of natural materials and the determination of mechanisms of concentration of radionuclides in products and waste releases into the environment.
(c) The development of standards and guides for control of exposure to natural sources in industry. These should include acceptable risk boundaries for optimization and the establishment of intervention levels.
(d) The establishment of radiation and waste safety profiles, action plans and procedures to monitor implementation in Member States.
(e) The maintenance of a strong safety culture.
(f) The solution to the problem of losing skilled and experienced employees in the future.

The improvement of occupational exposure control is an important area when updating radiation safety standards; in some cases this problem can only be solved by good collaboration between radiation protection organizations and scientific institutions. In this process, particular attention should be given to:

(a) Methods for routine individual monitoring of internal exposure to obtain reliable information on compliance with standards. In this process, uncertainties in dose assessment should be taken into account.
(b) Methods for planning occupational exposure using the ‘as low a reasonably achievable’ (ALARA) principle: dentification of groups of workers likely to be subject to higher exposures; analysis of operations that lead to high exposures; investigation of types of irradiation field (gamma, neutrons, etc.); analysis and improvement of monitoring systems; and qualification and training of workers, etc.

For many radionuclides, the protection of female workers also provides sufficient protection to the embryo or foetus. However, there are a number of radionuclides for which a chronic intake by inhalation at levels close to the dose limit for workers may result in an effective dose to the offspring of up to some tens of millisieverts, depending on the period of inhalation. For certain types of incident, especially during pregnancy, doses to the embryo or foetus may be higher than the effective dose to the mother. Adequate working conditions, justification of a given practice and optimization of radiation protection for female workers are the key points.

A European Worker Passport (EWP), the property of the worker, has been proposed for facilitating movement of contract workers in regulated nuclear installations (not only nuclear power plants) within the European area. The goal is to reinforce their dosimetric and health medical follow-up in conformity with the law of each country. The EWP is not intended to replace national dosimetric data on the occupational health of workers. That proposal may be useful for transient workers but it should not undermine the licensees’ obligation or the regulatory authorities’ requirements.

The European ALARA network continues to increase in size, covering more countries in Europe and proposing new means for facilitating ALARA implementation in radiation protection practice. The network is a useful tool for:

(a) Promoting the efficient and effective application of the ALARA principle at regional level,
(b) Providing a means for improving the feedback of experience,
(c) Preparing proposals for the appropriate use of optimization to control all types of exposure.

The implementation of similar ALARA networks in other regions was identified as an important issue for the future.

It was suggested that the International Labour Organization’s Safety Convention 115 could be used more as a tool, and that the ‘special circumstances’ of the BSS may no longer be required. Three direct actions were suggested:

(1) Update Convention 115 to make the language more relevant and to include reference to the BSS,
(2) Find a mechanism to investigate the situation on implementation of the Convention in non-Member States of the IAEA,
(3) Analyse the possibility of integration with other occupational health and safety measures.

TOPICAL SESSION 4

MONITORING OF OCCUPATIONAL RADIATION EXPOSURES

Chairperson's Summary
K. Fujimoto
Japan

At first, C. Wernli from the Paul Scherrer Institute in Switzerland presented his keynote paper. He covered whole aspects of occupational radiation monitoring including the purpose of radiation monitoring, quantities and units, present status of monitoring practices, recent development of dosimetry, problematic areas and future needs, referring to related IAEA Safety Series publications. His highlights are included in the following summary. Then, D. Cavadore, from COGEMA in France, reviewed 20 papers in his capacity as rapporteur. His findings are also included in the following summary. Following the two presentations, the chairperson made some comments to facilitate the discussion. Intensive discussion followed the presentations.

This session was intended to cover at least the following four aspects:

(1) Individual monitoring and exposure assessments for external and internal exposures;
(2) Monitoring of the workplace, monitoring techniques, biological dosimetry;
(3) Recording and reporting procedures;
(4) Intercomparison programmes.

As regards the first aspect, several papers were presented and described successful monitoring performances for external exposure. External monitoring of photons is relatively easy and many commercial services are available. However, some difficulties are encounted with beta and neutron dosimetry, although a bubble detector and an electronic dosimeter using a silicon diode were demonstrated as giving good performance for neutron measurement. In addition, the questions of who should be monitored and how it should be performed, including the use of background subtraction, have not clearly been answered yet, although some instruction regarding acceptable uncertainty range is given in Safety Guide No. RS-G-1.3 (Assessment of Occupational Exposure Due to External Sources of Radiation)

Internal dose assessment is recognized as being more difficult than external dose assessment and it is still in a formative state, although several papers were presented on how to overcome some difficulties. Some countries have no proper internal dose assessment system, although there is a possibility of internal exposure in various facilities such as mining, milling, research, radioisotope production and hospitals. Further improvement is required in internal exposure assessment. It is necessary for the IAEA to help some countries improve their internal dose assessment capabilities.

As regards the second aspect, that of monitoring techniques, new monitoring techniques for external and internal radiation were presented. In particular, direct electronic readout dosimeters could be useful tools and in some countries they are already recognized as a being a legal dosimeter. Personal dosimetry service accreditations were also presented and demonstrated good performance. No biological dosimetry was presented. In an accidental exposure, chromosome aberration analysis is one of the useful techniques for dose estimation, although not so many countries have such a capability.

As regards the third aspect, recording and reporting procedures, no paper touched on this clearly except that given by the keynote speaker (C. Wernli). However, this is an important issue. The United Nations Scientific Committee on the Effects of Atomic Radiation Report 2000 mentioned that it had difficulty in compiling or comparing the data supplied from many parts of the world owing to the lack of a standardized format for monitoring data. For ease of comparison and compilation it is required to have standardized data formats for recording and reporting. Dose distribution of occupational radiation exposures and their trends could be a good measure of the overall quality of the radiation protection infrastructure. Therefore, monitoring results should be used not only to check compliance with regulations but also to improve the optimization of radiation safety. In addition, occupational dose records should be maintained by a central dose registry system. That system is especially useful for workers who change their jobs. This situation could be further improved by a new international convention. However, some concerns are raised on recording level and identification of name when the database becomes larger, especially with regard to a foreign workforce.

Regarding the fourth aspect, intercomparison programmes, several papers were presented on this topic. The intercomparison exercise is essential to keep a high quality of performance of dosimetry service. It was found that results in some countries were not satisfactory. Further improvement is necessary, especially in Latin America.

Some problems were recognized in the following areas. Proper calibration was not performed with regard to the energy and irradiation conditions. Delayed adaptation of the International Basic Safety Standards (BSS) was found and that they used the old dose limit of 50 mSv/a and old terminology. Misunderstanding of the optimization was also found. It should be emphasized that compliance with dose limits or dose constraints is not proof of optimization.

The large demand for occupational monitoring attracts commercial companies to take over and control the market. Such large commercial dosimetry services have the advantages of offering well-developed, standardized methods, entailing low cost to the customer. On the other hand, the local expertise may diminish and the flexibility for site specific solutions may become limited.

In conclusion, certain progress has been made in occupational radiation monitoring. However, additional efforts are needed to improve the following aspects. Individual monitoring for neutron, beta and internal exposure is still a challenge. For neutron dosimeters, energy dependence of response, sensitivity and dynamic range are limiting factors in most available systems. For beta radiation, new designs of detector that make them comfortable to wear and less energy dependent are still needed. Active devices are still missing. Optimization of monitoring practice is another concern. Who should be monitored? How should it be performed? National dose registries have been set up in several countries; some others do not envisage a centralized dose registration system. Standardization of data formats for recording and reporting is required for ease of data compilation and comparison. Development of harmonized criteria or requirements for the adoption of direct electronic readout dosimeters is required for legal dosimeters. Some countries have not updated their regulations in accordance with the recent BSS. They use different quantities and units, hindering ease of international communication.

TOPICAL SESSION 5

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

Chairperson's Summary
J. Liniecki
Poland

The keynote paper, rapporteur's report and discussion during the session led to the several conclusions.

The application of ionizing radiation in medicine for diagnosis and treatment takes place within the framework of several specialities:

(a) X ray diagnostics,
(b) Interventional radiology,
(c) Nuclear medicine,
(d) Radiation therapy.

The benefits to human health from these practices are extremely valuable when indications are appropriate (justification) and performance of the respective procedures is qualitatively satisfactory.

Great benefits to human health are accompanied by some risk of deleterious effects occurring. Optimizations of the patients' protection depend upon obtaining the required diagnostic information of good quality at possibly low doses, and in therapy on accurate delivery of the prescribed treatment dose. These are, however, requirements of good medical practice, which is not the subject of this Conference.

Exposure of workers who perform diagnostic and therapeutic procedures is an unavoidable part of the risk that accompanies the health benefits obtained. These workers form the largest, or one of the largest, groups of people in the world exposed occupationally to ionizing radiation.

In developed countries, exposure of workers in radiotherapy and X ray diagnostics has been progressively reduced over the last decade and has reached the level whereby annual doses to an overwhelming majority of the personnel are lower than the current dose limits. Percentages of yearly doses in excess of 10 or 15 mSv are very small and such events have a sporadic character. It is well understood that the magnitude of occupational exposure in these two specialties has reached a level that is consistent, on the basis of common sense, with the concept of optimized protection.

However, it was stressed by participants of the discussion that mean doses reported do not provide full information on the magnitude of exposure and the collection of relevant enquiries in future should aim at obtaining data characterizing the distribution of doses in exposed worker populations. The practical aim of monitoring should consist of identifying potential situations and individuals that are likely to incur exposure substantially higher than the typical one, where corrective action and further optimization of protection would seem necessary. This applies in particular to those regions of the world, mostly developing countries, where average exposure is still evidently higher than that in developed countries.

Similarly, occupational exposure in diagnostic nuclear medicine in developed countries has now reached levels that can be assessed as reflecting optimized protection. In recent years, wider introduction of positron emission tomography methodology and some new therapeutic procedures have led to some increase in average exposure, understood as the annual value of the personal dose equivalent. It seems, however, that doses to the hands of radiopharmacists have not been properly monitored and assessed. There seems to be a potential for undesirably high exposure of hands in this occupational group. Therefore, systematic assessment of hand doses should be carried out and appropriate conclusions drawn.

The exposure of medical personnel performing interventional radiological procedures seems quite high, both when personal dose equivalents and doses to hands and eyes are considered. Some measurements point to obviously excessive doses to mostly exposed parts of the body.

The action aimed at the reduction of occupational exposure in interventional radiology should proceed along the following lines:

(a) Appropriate education and training of personnel in both methodology of work and in principles of radiological protection. This seems particularly important as a high proportion of practitioners undertaking interventional practice are not radiologists, but have specialized in other areas.
(b) Practice of interventional radiology should be allowed only upon demonstration that the equipment to be used meets proper technical requirements.
(c) Work should be undertaken to formulate standards for monitoring the exposure of persons engaged in interventional practices. These standards should enable adequate estimation of effective doses and absorbed doses to hands, arms and, perhaps, eyes.
(d) Attempts should be made to elaborate and implement the methods that would signal to the performing interventionist the magnitude of their exposure, actual dose rate and duration of the performance.
(e) Personal protection equipment should be further optimized, but only if feasible.
(f) Close co-operation of the interventionist team with medical physicists should be effectively encouraged.
(g) Development of safety culture in interventional radiology should be promoted by making appropriate arrangements for quality management, including internal and external audits.

Owing to the specific character of interventional radiology, its value in saving human health and life, associated stresses to the performers and the usual heavy workload they experience, the approach to optimization of protection of medical personnel in high exposure areas should give priority to education, training, persuasion and information exchange over merely restrictive actions.

Promotion of development of radiological specialities and practices in developing countries should go hand in hand with promulgation of radiological protection and safety culture.

TOPICAL SESSION 6

OCCUPATIONAL RADIATION PROTECTION IN WORKPLACES INVOLVING EXPOSURE TO NATURAL RADIATION

Chairperson's Summary
K. Ulbak
Denmark

Highlights of the keynote paper and rapporteur are summarized as follows:

(a) Natural radiation is an inescapable feature of life on earth: all people exposed to a background level roughly between 1 and 10 mSv/a, with a global average of 2.4 mSv/a.
(b) Occupational exposures exceeding 1 mSv/a have been recorded in:
 (i) High altitude flying,
 (ii) Mining and mineral processing operations,
 (iii) Oil and gas operations,
 (iv) Subsurface and above ground workplaces (radon).
(c) Reference levels can be established (e.g. Bq/g resulting in a dose of 1 mSv/a).
(d) Exemption and clearance levels must be used with caution.
(e) The number of exposed workers above 1 mSv/a is higher for natural sources than for human-made sources and may be significantly higher than the estimate made by the United Nations Scientific Committee on the Effects of Atomic Radiation.
(f) The enhancement in occupational exposure due to human activities needs to be controlled.

Basic recommendations and regulations regarding inclusion of exposure to natural radiation in workplaces are summarized as follows:

(a) International Commission on Radiological Protection (ICRP) Publication 60 (1991) addresses the following:
   (i) Workplaces identified by regulatory agencies,
   (ii) Operation and storage of materials with significant traces of natural radionuclides,
   (iii) Operation of jet aircraft,
   (iv) Space flight,
   (v) Radon in workplaces.

(b) The International Basic Safety Standards (BSS) (1996) address the following:
   (i) Underground mining of coal and of phosphatic and other minerals,
   (ii) Radon in workplaces.

(c) The European Basic Safety Standards (1996) address the following:
   (i) Radon, thoron and gamma exposure (spas, mines, underground workplaces and surface workplaces in identified areas);
   (ii) Operation with, and storage of, materials with enhanced levels of natural radionuclides;
   (iii) Production of residues with enhanced levels of natural radionuclides;
   (iv) Aircraft operation.

Highlights from discussion and issues of future concern are as follows:

(a) Identification of new areas of enhanced exposure to natural sources is to be expected (e.g. filter sand and sludge in waterworks).

(b) Definition of ‘radioactive ore’ must be independent of external factors (e.g. uranium price).

(c) Workers exposed to natural sources should be given the same level of protection (optimization, dose limitation) as workers exposed to human-made sources.

(d) Identification of ‘enhanced’ exposure situations and decision made on relevant control programme adapted to the actual situation.

(e) Concentration (identification and dose reduction) on workers incurring the highest exposure, comparable to other areas (medical, nuclear), e.g. frequent fliers (couriers).

(f) Radiation protection should, as far as possible, be integrated in the general worker protection regime (e.g. ordinary dust control).

(g) Issues on exemption, clearance, commodities and waste are not necessarily linked to exposure of workers to natural sources.

(h) Definitions of the meaning of ‘significant traces’ and ‘enhanced’ according to the ICRP and the BSS to:
   (i) Provide limited international numerical guidance regarding specific areas,
   (ii) Address the need for international guidance on the inclusion of exposures to natural radiation at workplaces.

TOPICAL SESSION 7

OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL AND RESEARCH FACILITIES

Chairperson's Summary
B.C. Bhatt
India

There has been a significant increase in the industrial applications of radiation sources globally and, as a result, the number of workers in this field is steadily increasing. The worldwide average annual collective dose from industrial uses, over the period 1975–1984, was about 900 man·Sv, which decreased to 360 man·Sv by 1990–1994. The average annual individual dose in this field followed a similar trend, decreasing from 2.1 mSv in 1975–1979 to 0.51 mSv in 1990–1994. Although an analysis of occupational dose records indicates general compliance with the safety standards, serious overexposure cases, sometimes involving fatalities, are continuing to be reported as a result of the use of radioactive materials in industrial applications.

1. FINDINGS AND CONCLUSIONS

Although the issues associated with radiation protection are generally common to all uses of radiation, there are a number of challenges specifically associated with industrial uses:

(a) There is reduced opportunity for defence in depth to protect users. Instead, greater reliance is placed on proper work procedures and adherence to good safety procedures by the operators.
(b) There are a very wide variety of conditions encountered, which can make it more difficult to standardize safety equipment and procedures to the desired level of safety. This increases the probability of an unsafe condition continuing uncorrected.
(c) There are greater difficulties in ensuring that personnel in this field have received adequate training. In addition, the nature of the work can mean that it is more difficult to confirm that proper procedures are being followed.
(d) Dissemination of information on best practice and feedback are more difficult.
(e) Co-operation and communication are more difficult in a diverse field such as this.

Reviewing the submitted papers, it was noted that, for industrial radiography in particular, the same problems have been encountered for the last three decades and that this field continues to be a problem area. A key element of this is because radiographers do not take simple precautions, such as monitoring ambient radiation levels after each and every exposure, which would eliminate 80–90% of incidents. In addition, it can be difficult to get radiographers to wear dosimeters or personal alarm monitors routinely.

A particular issue that was identified again, as it has been in other sessions, is how to transfer the vast quantities of very useful information that exist to the workplace. The major problem area is that such information is often in English, rather than the local language.

The Conference noted that many industrial uses involve small organizations which do not have access to full-time radiation safety personnel. It was noted that qualified experts acting as consultants to these organizations can have a positive impact.

In addition, radiation safety training is often limited to the minimum required by regulatory authorities, which can reduce the safety margin for normal operations, and still further for unusual incidents, because an operator may not have sufficient training to correct unusual unsafe conditions. Some countries (e.g. the United States of America) require that anyone acting as an industrial radiographer successfully completes an approved examination, and this was considered to be a positive approach. The primary aim of training and certification should be that anyone acting as an industrial radiographer should have adequate knowledge about the basic principles of radiation protection and the practical safety measures they should use.

Occupational exposure in a university environment, particularly that due to a research reactor or to other significant uses, has some typical characteristics that provide challenges to the efficient and effective implementation of radiation protection. In particular, the large percentage of the staff that is either temporary or mobile poses problems in respect of training, familiarization and management.

The potential for accidents and additional contributions to routine exposures can be minimized by the speedy disposal of spent sources. To achieve this, it is important that national arrangements to deal with spent sources are available and can deal with situations where no funding for disposal is available from the owner (if there is one).

Reconstructive dosimetry in any radiological emergency situation is effected by simulation of accident conditions and it may be used to estimate more accurately the actual dose received by the operator, and hence aid the proper medical evaluation of, and treatment procedures for, the involved victim.

There should be clear guidelines for the repair and maintenance of radiation equipment employing radiation sources to ensure that personnel are not subjected to high radiation exposures and do not suffer radiation injury during maintenance work.

Co-ordination and communication among regulatory bodies, other agencies and users are vital, so that there is a broad understanding of safety problems, lessons learnt and remedial measures taken in various safety issues.

With regard to industrial radiography, it was noted that:

(a) In many situations, it may be advisable to require that industrial radiographers work in two-person teams to serve as a check and balance mechanism to ensure procedural adherence, e.g. the performance of radiation surveys at appropriate times.
(b) Radiographers should wear personal alarm dosimeters in addition to using personal dosimeters routinely.
(c) The success of any measure directed towards the reduction of radiation overexposures amongst industrial radiographers may well depend on the ability of regulatory authorities to cause radiographers to recognize the benefit, beyond regulatory requirements, of radiation exposure control during source operations.

It was also noted that in industrial radiography, client organizations can exert pressure on industrial radiography companies to improve their radiation protection procedures and culture. There is, therefore, value in raising the awareness of the client organizations in respect of radiological protection issues. In particular, it can be beneficial to provide checklists of the radiation protection features to be expected when a radiography company is operating on their premises.

Our goal should be to reach a point where overexposures are so infrequent that our primary focus is on optimization of routine exposures.

2. RECOMMENDATIONS

Industrial radiography continues to be a problem area, associated with relatively high operational doses and a high frequency of accidents. The discussion session identified many good sources of information on learning lessons from accidents, but noted that there were still difficulties in making the information directly available to workers in their national/local language. The use of radiation protection newsletters for reporting incidents/accidents was highlighted. In addition, use of two-person teams for radiography and use of alarm dosimeters was also highlighted.

It was identified that the use of qualified experts, acting either as external consultants to user organizations or internal staff, can be very beneficial.

It was also recognized that adequate training of users of radiation sources is necessary. Need based training programmes specifically tailored to various industrial and research applications of radiation are necessary. Adequate training and retraining increases the likelihood that the operators will follow the safety procedures under the normal conditions, and will be better equipped to respond to accidents/unusual incidents.

TOPICAL SESSION 8

OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR FACILITIES

Chairperson's Summary
A.P. Panfilov
Russian Federation

1. RADIOLOGICAL PROTECTION STATUS

The application of occupational radiation protection in nuclear facilities signifies a situation where dose limits are being achieved, often by a considerable margin. The 'as low as reasonably achievable' (ALARA) principle is applied in one form or another and is often claimed as the means by which significant improvements have been achieved.

Achievements in one nuclear area should not necessarily set goals for others.

In most facilities the only major concern referred to is external gamma radiation. There is little personal monitoring reported for neutrons and extremity exposures suggesting that these are now of lesser importance.

The importance of a formal method of ensuring the appointment of educated and trained personnel such as radiation workers is noted.

2. INDIVIDUAL DOSE CONTROL

The use of collective dose is noted and increases in collective dose should not be used as a means of restricting individual doses. There is a move to a workforce culture that encourages more personal control over working arrangements.

3. DOSE REDUCTION

The term ALARA has been used in many countries as a synonym for dose reduction. It is possible that placing more emphasis on individual dose control could generate a move from collective to individual dose reduction techniques.

A further message is the importance of collecting good data from the facilities to enable effective interpretation and identification of trends.

4. OPTIMIZATION

The optimization process is time dependent, with new facilities at the design stage presenting more opportunities for eliminating hazards. Older facilities are often constrained in the control options available. This may be a timely opportunity to consider whether facilities can be optimized for their remaining life-cycle, including decommissioning and remediation, i.e. improvements to further reduce dose during operation may have an adverse impact on decommissioning.

Cost–benefit analysis remains a valuable tool of optimization, providing transparency of decision making.

5. CONTROL OF CONTRACTORS

Papers and discussion point to the often significant difference in exposures between the workforce and itinerant contractors. The internal dose resulting from work is of significance in nuclear facilities and there are occasions when the implications for control do need to be considered for this group.

6. NON-ROUTINE EXPOSURES

Non-routine exposure control is a requirement of the International Basic Safety Standards (BSS) and should be properly addressed perhaps at an international seminar.

7. COMMUNICATION

As regards communication, several aspects are stressed:

(a) The importance of communication between all stakeholders is noted,
(b) The language problem should be addressed,
(c) Transparency of communication is important.

8. DEMONSTRATION OF SAFETY

The existence of clear standards is important to regulate the safety of civil nuclear power and the BSS are important in this regard. Development of a methodology to demonstrate safety practice should be given consideration.

9. LEARNING FROM EXPERIENCE

An important feature of effective safety management systems is the ability to learn from experience and to seek continuing improvement. The information gained also enables safety to be built in, providing defence in depth. There is also great benefit in being able to exchange information on successes and failures in the safety field worldwide and to new generations of radiation protection professionals. The international community needs to consider whether more can be achieved, particularly when the languages are not common.

10. CONCLUSIONS AND ISSUES OF FUTURE CONCERN

Papers and discussion are very encouraging and reflect the international and national efforts being made to meet clear radiological protection standards. The success of occupational protection worldwide in nuclear facilities is demonstrated but vigilance is still needed. There would be merit in identifying the critical issues of future concern, including:

(a) Movement towards individual dose reduction, particularly for the highest exposed workers.
(b) Proper control of contractor individual dose and its ALARA reduction.
(c) Special attention to radiation protection culture differences between facilities.
(d) Wide and transparent involvement of, and communication with, workers when considering measures regarding occupational exposure control.
(e) Optimization options at old facilities are limited and should involve all phases (including decommissioning).
(f) Optimization approach could be transferred to other hazards (e.g. chemicals).
(g) Overcoming language barriers when exchanging experience and proper experience transfer to new generations of radiation protection professionals.
(h) Consideration given to the fact that radiation is only one hazard and must be balanced with the other hazards encountered in the workplace. At the international level there may be merit in considering how this might be achieved.

TOPICAL SESSION 9

PROBABILITY OF CAUSATION OF OCCUPATIONAL HARM ATTRIBUTABLE TO RADIATION EXPOSURE

Chairperson's Summary
D.J. Beninson
Argentina

This very complex subject was the topic of two invited lectures, which also discussed several aspects from contributed papers.

The first of these papers dealt with epidemiological studies of occupational exposure to ionizing radiation. Risk models underlying radiation protection are mostly based on studies of specially irradiated groups, the most important being the survivors of the atomic bombs in Hiroshima and Nagasaki. Epidemiological studies of workers exposed to radiation will eventually provide a direct check on the validity of the models at the real levels of dose from occupational exposures.

Large studies of workers exposed to radiation, especially those in nuclear activities, have the potential to result in relevant risk coefficients and to provide a check on a number of assumptions used at present.

The second invited paper reviewed the bases and practical aspects of current compensation schemes and essential tools — dose reconstruction techniques.

Most compensation schemes in the world do not have a specific design for workers occupationally exposed to radiation. Three countries have more specific compensation schemes. The three share the concepts of 'no fault of worker or employer' and that of 'proof of eligibility'. On the other hand, they differ in procedures and the key issue is what makes an efficient, timely and circumstance dependent compensation scheme.

The discussion covered many issues ranging from conceptual to practical aspects. Conceptual themes included the problem of induction based on Bayes theorem and the use of experience, the relation of dose and number in the exposed group for similar statistical power, and the problem of different cancer distributions found in life studies of 17 countries. Many practical issues discussed can be related to dose reconstruction evaluations, involvement of stakeholders and possible assistance of international organizations.

As a conclusion of the discussions the following recommendations were made, namely, that:

(a) The international agencies should encourage international collaboration on epidemiological studies of workers.

(b) Dose reconstruction is an essential component which must address the uncertainty in the dose.

(c) Compensation schemes need to be scientifically and evidence based.

(d) The international agencies need to continue discussions with a view to the preparation of guidelines and to assist countries that are interested in establishing compensation schemes.

(e) Stakeholder involvement is strongly desirable.

ROUND TABLE 1

IS THE CO-OPERATION BETWEEN REGULATORS, EMPLOYERS AND WORKERS ACHIEVING OPTIMUM OCCUPATIONAL RADIATION PROTECTION?

Chairperson's Summary
W. Bines
United Kingdom

Common themes and future needs emerging from the statements and discussion, some echoing points from the previous session, were:

(a) Unclear demarcation of responsibility between the regulator and the employer, particularly in respect of control of natural radiation sources.
(b) Difficulty in defining 'the regulator' when several departments and agencies were involved in radiation protection nationally.
(c) Examples of good stakeholder involvement were available, not just problems.
(d) Need to address the question of whether there is a threshold below which optimization considerations are not necessary.
(e) Need for trust between all parties, built on genuine openness and a 'no blame' culture.
(f) Problems caused by increasing use of contractors in the nuclear industry.
(g) Need for employers to consult workers more.
(h) Expertise of radiation protection professionals should be used more, e.g. as mediators and educators.
(i) Mechanism needed to check the real influence of stakeholders and their level of satisfaction.
(j) Need to educate workers (i.e. beyond their immediate job needs) to allow proper involvement and evaluate the resource implications of this.
(k) Further clarify and co-ordinate the roles of the different international organizations and harmonize terminology.
(l) Make proper provision for non-nuclear uses of ionizing radiation, (e.g. medical) and take account of differing resource availability.
(m) Unnecessary 'tinkering' with (i.e. changing) standards caused anxiety and misunderstanding.

Possible future actions at international/national level (and basis for potential recommendations, subject to later discussion), including those where the actual action might need to be taken at national level, were to:

(a) Clarify roles of international bodies (possibly agree a ‘lead’ organization?) and adopt harmonized terminology;
(b) Encourage clarification (and if possible simplification) of responsibilities, particularly in respect of ‘the regulator’;
(c) Encourage education of all parties to a similar standard, to enable true stakeholder involvement and consider how this might be achieved;
(d) Encourage (require?) employers to consult their workers more and develop locally agreed measures of optimization;
(e) Involve all stakeholders (including environmentalists) from the early stages of development of proposals, to help ensure ‘ownership’ of decisions;
(f) Share more examples of good practice (internationally and nationally);
(g) Make better use of the expertise of radiation protection professionals;
(h) Encourage two-way feedback, to check understanding and stakeholder satisfaction;
(i) Ensure needs/resources of *all* users of ionizing radiation are addressed.

ROUND TABLE 2

HAS THE CONTINUED IMPROVEMENT IN RADIATION PROTECTION STANDARDS GONE FAR ENOUGH IN COMPARISON WITH STANDARDS FOR OTHER HAZARDS?

Chairperson’s Summary
A.C. McEwan
New Zealand

Round Table 2 was introduced by three panellists. P. Deboodt discussed generalized approaches to the control of hazards through an optimization process, extending the ‘as low as reasonably achievable’ (ALARA) principle to ‘as safe as reasonably achievable’, or ‘ASARA’. He also raised the issue of ‘risk transfer’, where attention to one kind of risk may result in increased exposure to a different kind of risk, or a transfer of, say, occupational risk to public risk. He noted the importance in risk management of the involvement of all parties and the use of common language in discussion of risks. G.P. de Beer explored the influence the level of development of a country may have on risk perception and acceptance, noting that in a number of developing countries allocation of limited health and safety dollars is best directed to the area of greatest potential gains. This raised the question of what resources should be devoted to radiation protection in countries with HIV infection rates of up to 40%, or which lack clean water supplies for sectors of the population. A further consideration was that HIV infection affected immune response and could thereby alter risks from occupational exposures. Both presentations were summarized by the rapporteur for Topical Session 1 and so are not considered further here, although the issues raised underlay much of the ensuing discussion.

The third panellist, R. Coates, gave an assessment on where occupational radiation protection has got to, noting that through the application of ALARA there has been a downward trend in exposures over the last two decades, particularly with respect to higher doses. He observed that apart from control of natural radiation exposures, which still presents some challenges, generally, risks from occupational exposure are well understood, well quantified and bounded at the individual worker level, and broadly acceptable, so there was little to be gained by tightening the hazard control framework. He alluded to the issue raised by G.P. de Beer and posed the question of whether the current standards might be too stringent in some very poor countries, where scarce resources might be better spent on factors posing greater risks. This initiated discussion on whether different standards or dose limits might be applied in different countries. This has a certain logic in that dose limits are set by the International Commission on Radiological Protection on the basis of a societally based assessment of the tolerability of risk. If risks from other causes, which could be linked with factors such as unemployment, are high, could higher doses from radiation be accepted? This would not necessarily lead to higher risks since, in a poor country with low average life expectancy, the probability of expression of risk from radiation received through occupational exposure is considerably reduced. The opposing and consensual view was that the idea of having different standards in different countries, an idea which had been raised in previous forums, was not an acceptable situation for several reasons:

(a) A relaxation of standards of protection conveys at least the perception that lessened standards and therefore higher risks are being imposed on a population already exposed to high risk. This is demeaning to people in developing countries.
(b) The main socioeconomic impetus for acceptance of different standards was arising from the mining industry where in fact significant dose reductions and ‘to within’ dose limits could be achieved with relatively little cost to the industry. By contrast, major dose reductions in mines to levels comparable with those to occupationally exposed persons in other industries (e.g. the nuclear industry), would cost very substantial sums.
(c) International standards need to be recognized and accepted internationally. This applies not only to standards for dose limits but also to derived quantities such as activity concentrations in commodities in international trade. Further, there is a major credibility issue if different standards are adopted and this applies particularly in regard to related standards which are applied, for example, in the area of nuclear safety.

It was further observed that the existing standards do make provision, through the process of optimization, for social and economic conditions to be taken into account and that in different countries optimization might be expected to lead to different acceptable solutions.

R. Coates proposed that the application of ALARA is, and should remain, the key controlling influence in occupational radiation protection and noted that it has engineering and management systems and safety culture components. While engineering solutions were expensive, the other two components were generally not, and could in fact result in cost reductions, i.e. a 'win–win' optimization. R. Coates further proposed that the focus of ALARA should be the higher personnel doses; for low levels of occupational exposure, say 2 mSv/a, exposure reductions make no measurable change in the risk profile of the individual and it was wasteful of resources, including that of regulators, to seek reductions. Dose reductions could, however, be discussed between management and workers. This strategy had a measure of support. Risks arising from potential exposure still require regulatory oversight.

Conclusions and recommendations from Round Table 2 are summarized as follows:

(a) Radiation protection standards generally have gone far enough in comparison with other standards. Implementation of the standards remains important, particularly for the avoidance of accidents.
(b) A unified approach to the control of different occupational hazards appears feasible with ALARA being extended to ASARA, but requires common language and both management and worker involvement.
(c) In poor developing countries, radiation safety may be a very minor health and safety issue.
(d) Radiation protection standards should not be relaxed in poor developing countries in the expectation that this could create employment opportunities; the optimization of protection allows local socioeconomic factors to be taken into account.
(e) Optimization (the application of the ALARA principle) should continue to have a governing role in the achievement of low occupational doses.
(f) In the process of optimization, attention to management systems and safety culture may result in the achievement of both dose aversion and cost reduction.

ROUND TABLE 3

CAN CONTROL OF OCCUPATIONAL EXPOSURE TO NATURAL RADIATION BE MADE COMPATIBLE WITH CONTROL OF OCCUPATIONAL EXPOSURE TO ARTIFICIAL RADIATION?

Chairperson's Summary
G.C. Mason
Australia

M.A. Waters summarized the status of occupational exposure for aircrew, including statistics on exposures, and discussed International Commission on Radiological Protection guidance on, and European Union requirements for, radiation protection. She noted that in the United States of America there is no requirement to treat aircrew as occupationally exposed. It is clear that engineering controls are not possible, but administrative controls may be appropriate in some circumstances, for example, to protect the foetuses of pregnant workers. She pointed out that dose estimation, rather than dose measurement, is sufficient in most cases and drew attention to questions concerning the treatment of pregnant women and frequent business travellers.

L. Tommasino stressed the need for the flexible regulatory treatment of natural radiation sources and also the desirability of harmonized international practice. He noted the inappropriateness of a 10 μSv/a criterion for exemption of natural sources and the difference between practices, such as uranium mining, and interventions, such as the treatment of radon in workplaces. He also pointed out that once an activity involving natural sources has been categorized as a practice, there should be no double standards with regard to radiation protection requirements compared with those for artificial sources. L. Tommasino commented on the European Union strategy of defining work activities involving exposure to natural sources.

J. Piechowski drew attention to the differences between the nuclear and non-nuclear industries, although the radiation protection objectives are the same. For natural sources, exposures are fairly stable and predictable, with little likelihood of large accidental exposures. He felt that there was a need for more specific guidance on monitoring and assessment of internal exposure from natural sources. Specific radiation safety practices also need to be developed for natural exposure situations. He also compared radiation protection measures and conventional occupational health and safety practices, noting the need for a harmonized approach.

J. van der Steen noted that exposure from natural sources is estimated to contribute about 80% of occupational exposure worldwide and that some individual doses can be significant. One of the problems is lack of awareness in industries handling naturally occurring materials, leading to an absence of desirable protection measures. Other problems relate to the need for sensible regulations and guidance. There is an essential need for criteria for deciding when an activity should be regulated; the concept of exemption at dose levels below 10 μSv/a is not appropriate. The 'grey' area between practice and intervention is a particular problem and requires clarification. There is also a need for further guidance on radiation control measures.

The Chairperson drew attention to existing guidance on dealing with exposures from naturally occurring sources, particularly that contained in the Safety Guide on Occupational Radiation Protection (RS-G-1.1), jointly sponsored by the IAEA and the International Labour Office. Discussion was vigorous, with several speakers expressing concern at the lack of clarity and completeness of current recommendations. It was suggested that examples of exposure situations could be reviewed from a perspective of optimizing radiation controls in order to develop specific guidance. There was a call for a definition of 'radioactive substance', which at present is missing from the International Basic Safety Standards and related guides. More than one speaker noted that once it had been decided to regulate an activity as a practice, the same rules as for artificial sources of exposure should apply. These should include, however, the possibility of a graded approach to regulation matched to the degree of hazard. A crucial question is to decide what exposures can be considered to be unamenable to control and thereby excluded from regulatory requirements.

As input to the findings and recommendations of the Conference, the following comments may be made:

(a) The IAEA should initiate a task for settling detailed guidance to assist regulators in deciding what exposures are unamenable to control.
(b) This guidance should be incorporated into recommendations for establishing which industries involving exposure to natural sources of radiation should be subject to control as practices, including advice on graded approaches to regulatory requirements that would similarly apply to exposures from human-made sources.

ROUND TABLE 4

WHAT ARE THE MAIN PROBLEMS IN OPERATIONAL IMPLEMENTATION OF RADIATION PROTECTION STANDARDS?

Chairperson's Summary
I. Othman
Syrian Arab Republic

Lui Hua summarized problems experienced in China such as delays in the finalization of legislation, lack of knowledgeable experts to conduct inspections of sources and problems associated with radiation protection in old facilities, e.g. higher occupational exposures, weak safety culture and bad designs.

P.M. Sajaroff presented problems from his worldwide experience. These related mainly to:

(a) Organizational deficiencies such as non-effective regulatory performance, inadequate technical competence in workers, employers and regulators, inappropriate discharge of management responsibility, weak safety culture and lack of an effective quality system;
(b) Unresolved or pending technical aspects such as exemption, clearance and action levels related to long lived radionuclides in commodities, identification of radioactive sources, the protection of comforters in paediatric radiology and occupational exposure to natural radiation in non-nuclear industries.

H.-H. Landfermann presented various theses and antitheses related to problems being experienced with the implementation of radiation protection standards. These related to special compensation arrangements, female employees, the split in responsibilities between employees and licensees, the movement of workers amongst countries with different national regulations and the value of alpha in the optimization.

I. Othman highlighted problems that are experienced in developing countries. These included:

(a) Problems that result from the fact that practices started operating before standards were introduced, e.g. resistance to change.
(b) Standards that do not reflect the real situation in the country.

(c) Problems related to the preparation of standards, e.g. availability of radiation experts knowledgeable about the country situation and vice versa.
(d) Unavailability or vagueness of standards.
(e) Lack of task specific training for operators, regulators and inspectors, resulting in misunderstanding of responsibilities.
(f) Lack of revision of standards after accidents or based on feedback from applicants.

During the discussion, a number of participants from developing countries highlighted the value of the IAEA model project, the benefits received through other means such as its regional agreements and the importance of strengthening co-operation among international organizations such as the IAEA, the International Labour Organization and the World Health Organization.

The following problem areas related to the implementation of standards were identified over and above those mentioned by the panellists:

(a) Training of final decision makers, e.g. legislators;
(b) Illicit trafficking of material;
(c) Wastage of resources on, for instance, quantification of doses of ground staff at airports;
(d) Clarification of the responsibilities of the regulator, operator, licensee (line management) and appointed radiation protection managers;
(e) Dose recording of contract workers;
(f) Exposure of female workers;
(g) The need to convert the IAEA safety standards into country specific regulations and guidance;
(h) The need for stability in IAEA safety standards;
(i) The need for commitment from the highest level in government and registrant/licensee management.

The IAEA has explained its initiatives in respect of a number of the above problem areas, for example, securing the commitment of governments as a prerequisite for participation in the model project, improving the understanding of radiation protection by final decision makers and providing the right persons with the right guidance.

A number of recurring themes were observed, such as:

(a) The importance of safety culture,
(b) Inadequate technical competence of regulators and operators,

(c) Difficulties with contract workers,
(d) Exposure to natural sources of radiation,
(e) Exposure of female workers.

Several recommendations are presented for consideration by the IAEA:

(a) In the context of occupational radiation protection, the IAEA should develop, implement and evaluate performance indicators related to:
  (i) Regulatory performance,
  (ii) Effectiveness of IAEA sponsored training,
  (iii) Safety standards development programme.
(b) Data provided by the United Nations Scientific Committee on the Effects of Atomic Radiation are used extensively for a variety of reasons, e.g. to evaluate the implementation of international occupational exposure standards, to facilitate information exchange and to determine future priorities. The IAEA should, as part of its co-operation with other international organizations, investigate mechanisms to improve the availability, consistency and reliability of the data provided by its Member States.
(c) The IAEA should develop guidance on effective ways of securing the highest level of commitment within organizations that require occupational radiation protection programmes.
(d) The IAEA should prioritize the resolution of issues related to the exposure of female workers.

ROUND TABLE 5

IS THERE A NEED FOR A MAJOR CHANGE IN ICRP RECOMMENDATIONS INVOLVING OCCUPATIONAL EXPOSURE?

Chairperson's Summary
A. Sugier
France

In the latest paper published by the International Commission on Radiological Protection (ICRP) concerning the evolution of its recommendations, the main commission indicates that the objectives of these new recommendations will be "to simplify and unify" the present system, and "to focus on real problems".

As far as occupational exposures are concerned, major modifications do not seem necessary and there was a general recognition during this Conference that the present system is working rather well.

However, the Conference has identified three real problems that any future recommendations of the ICRP should address:

(1) Particular attention should be given to the most exposed workers (transient workers, medical professionals, decommissioning workers, natural exposures are dealt with in item 2). In this respect, a key question for the ICRP is to recommend adequate tools to control these exposures. Two main approaches have been discussed during the various sessions: establishment of minimum standards of protection and implementation of optimization. A worldwide agreed standard level of protection is considered essential for the credibility of the system (be it called dose limit or protective action level). It should correspond to a risk comparable to other industries. The quantified value, which was debated, should be kept under review, recognizing that any changes in the numerical value would have a major impact. Optimization is seen as the main tool for efficient dose reduction. Concern has been raised that being 'number 2' in the hierarchy of the new system might weaken this important principle. One way to strengthen its implementation would be to define case specific dose targets or reference dose levels. In any case, stakeholder involvement at an early stage is now recognized as important to improving further the control of exposures by active participation of involved stakeholders in the decision framing and decision making processes related to radiological protection.

(2) The management of occupational exposure to natural radiations deserves careful attention in the future system of the ICRP. Data presented during the

Conference show that the number of concerned workers is certainly much higher than the present estimates. There is a clear need to define procedures on how to enter into the system — the main issue being amenability to control. But once in the system, all parties emphasized that the treatment should be consistent with the general system. The application of optimization will have to take account of social and economic factors, particularly in developing countries. In this context, the role of exclusion levels should be addressed.

(3) The clarification of the terminology appears necessary, particularly as regards detriment. Following the same line of thought, the ICRP sees a need to reconsider the definition of detriment. However, this should not be done without carefully considering that the appreciation of risk is an important and complex issue, which should not be oversimplified. In its reconsideration, the ICRP should clarify the following issues: characterization, quantification, comparison with other hazards and attributable risks. In this respect, concern has been raised that stability with the use of the present units and quantities be maintained.

OPENING SESSION

OPENING ADDRESS

T. Zeltner
Swiss Federal Office of Public Health,
Berne, Switzerland

On behalf of the Government of Switzerland, the Ministry of Home Affairs and the Ministry of Foreign Affairs, I am very pleased to welcome all of you to the International Conference on Occupational Radiation Protection: Protecting Workers against Exposure to Ionizing Radiation.

The Government of Switzerland is very happy to host this Conference, which is:

(a) Organized by the IAEA,
(b) Convened jointly with the International Labour Organization (ILO),
(c) Co-sponsored by the European Commission, and
(d) Held in co-operation with the OECD Nuclear Energy Agency and the World Health Organization (WHO).

We are very grateful to the ILO in Geneva for having made its headquarters available to us and also for permitting us use of its excellent infrastructure. We also think it a good sign for the workers that the first International Conference on Occupational Radiation Protection takes place on the premises of the ILO, the house of workers and employers, and in the neighbourhood of the WHO.

As host city to many international organizations, Geneva has become known as 'international Geneva'. It is home to a very wide range of international organizations active in areas as varied as humanitarian action, human rights, trade, environment and sustainable development, education and training, peacekeeping and security, meteorology, intellectual property, nuclear research, telecommunications and, last but not least, health and labour.

Switzerland has been an observer at the United Nations since 1948. After a long period of fruitful collaboration with many United Nations organizations, Switzerland is — finally — looking forward to becoming a full member of the United Nations in the course of this Autumn. On 3 March 2002, the people and the cantons of Switzerland authorized the Federal Council, on the basis of a referendum, to submit a request for admission to the United Nations to Secretary General Annan.

OPENING ADDRESS

T. Taniguchi
International Atomic Energy Agency,
Vienna

It is my honour and pleasure to welcome you on behalf of the Director General of the IAEA to this International Conference on Occupational Radiation Protection.

Occupational protection is the oldest branch of radiation protection. The very first radiation protection measures were introduced to prevent early researchers and medical practitioners from suffering deterministic health effects due to radiation exposure incurred in the course of their work. The International Commission on Radiological Protection (ICRP) grew out of radiologists' concern to protect themselves and their colleagues (as well as their patients). The IAEA, following on from the recommendations of the ICRP, established the first international radiation protection standards, and many of the IAEA's earliest safety standards dealt wholly or in part with the protection of workers.

Turning to the present, I think it true to say that occupational radiation protection is an international success story. Although the number of occupationally exposed workers has risen continuously, there has for many years now been a clear downward trend worldwide in the doses that workers receive in the course of their work. This trend can clearly be attributed to the widespread practical application of basic radiation protection principles, particularly the principle of optimization of protection, through radiation protection programmes, information exchange and work management.

This success story is an accumulation of the efforts of many individuals and teams at the local level as well as national authorities. But I think the international organizations represented here can take at least some credit, and I would like to mention three examples:

(1) The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), sponsored jointly by the IAEA, the International Labour Organisation (ILO), the OECD Nuclear Energy Agency (OECD/NEA) and the World Health Organization (as well as the Food and Agriculture Organization of the United Nations and the Pan American Health Organization), have provided a common international basis for translating the principles of the ICRP into actions by the operators of facilities, the users of radiation sources, individual workers and their regulators.

(2) In developing more detailed guidance on the application of the BSS, the IAEA's expertise in radiation protection, and its unique statutory function within the UN system to establish standards for occupational radiation protection, has been complemented tremendously by the ILO's ability to bring workers and

employers to the same table. It is well recognized that optimized radiation protection in workplaces can only be achieved if there is a strong commitment throughout the entire organization, from the top management to the workers.

(3) The Information System on Occupational Exposure (ISOE), operated jointly by the IAEA and the OECD/NEA, is emerging as a very valuable tool for improving occupational protection worldwide, by giving ready access to information on what can be achieved and how. Indeed, if I might briefly refer to issues beyond occupational radiation protection, one of my priorities as regards the IAEA's work is to enhance the global networking of safety knowledge and experience through more strategic application of IT based knowledge management. In this regard, I think the ISOE offers an example that may be followed and built upon in other areas of safety.

Having described occupational radiation protection as an international success story, I must add that there is no room for complacency. Not only do we need to continue with the measures that have brought such reductions in occupational exposure, but there are issues where there may be room for further improvement, and I would like to mention a few of them here.

The first issue is that there remain differences from country to country in the implementation of the current standards. These differences are individually small — for example, slight variations in quantities and units, or subtly different understandings of the allocation of responsibilities and obligations, for example between employers and licensees. However, if not addressed or at least better understood, the cumulative effect of these small differences could cause significant variations in the application of standards.

The second issue, and perhaps a more obvious one, is that of exposure to natural radiation sources in the workplace. There is a general understanding that employers must be expected to control such exposures when it is feasible for them to do so, and in some cases it has been defined more precisely what this means. However, the solutions to date have been somewhat ad hoc and piecemeal, and it may be that we need to find a deeper, more coherent policy for addressing this issue over a wide range of situations.

The third issue is that of probability of causation. Technically, of course, this is a very complex matter, but perhaps a policy issue can be more simply expressed. A number of countries have developed national compensation schemes that take account, in one way or another, of assessments of individual probability of causation. But is there anything that should be done at the international level to assist other countries in addressing the matter?

Finally, we may soon begin to see some exceptions in certain fields to the overall downward trend in occupational exposure. For example, although collective doses to workers at nuclear power plants are decreasing overall, relatively high doses have been incurred in some refurbishment and backfitting operations in some countries. If such operations were to become more common as the average age of reactors increases, this might start to affect the overall picture. We would also expect that the increasing need to decommission facilities and terminate practices would introduce more collective dose to workers. Of course, any increases that might occur would not necessarily indicate deficiencies in occupational radiation protection in these areas; they might simply be examples of more work meaning more dose. The ISOE should help us to follow developments on this issue.

I would like to add one further observation on the topic of decommissioning. The regulatory experience relating to occupational radiation protection during the termination of practices is much less extensive than that for the initiation and operation of such activities. The IAEA is planning to help fill this gap. In October, we are organizing an international conference in Berlin on decommissioning and the safe termination of practices, and the findings from that conference will influence our future work in this field. I anticipate that the discussions during the coming week on the occupational exposure of workers involved in decommissioning will be an important input to the deliberations of the Berlin conference.

Clearly, there is plenty for you to discuss this week. As has become the custom with the IAEA's radiation safety conferences, I would expect that we will use your findings and recommendations to develop an international action plan to strengthen occupational radiation protection, particularly through more integrated approaches to our assistance, and to our advisory and education and training programmes. I will therefore close by wishing you well in your deliberations, and I look forward to seeing the findings and recommendations to be presented by the Conference President.

OPENING ADDRESS

J. Takala
International Labour Office,
Geneva

On behalf of the Director General of the International Labour Organization (ILO), J. Somavia, I welcome you all most warmly. The ILO is extremely pleased to co-convene this important international conference.

This Conference is the result of close co-operation between the IAEA, the Swiss Government, the ILO and the co-sponsoring and collaborating organizations. We need co-operation because the protection of workers against exposure to ionizing radiation requires an integrated approach and the participation of all the stakeholders. I thank the IAEA for its commitment to interagency co-operation. I also thank the host country of the Conference — Switzerland. Without the Swiss Government's generous support and co-operation, it would have been impossible to have the Conference here today. I should like to thank as well the World Health Organization, the European Commission and the OECD Nuclear Energy Agency for their co-operation in organizing this event.

I am very happy that we have chosen the ILO as the venue of this Conference. As you all know, the ILO has a tripartite structure unique in the United Nations, in which employers' and workers' representatives — the 'social partners' of the economy — have an equal voice with those of the governments in shaping its policies and programmes. The Declaration of Philadelphia, which spells out the aims and purposes of the ILO, recognizes the obligation of the ILO to further, among the nations of the world, programmes which will achieve, amongst other things, the extension of social protection, the provision of comprehensive medical care and the adequate protection of the life and health of workers. Protection of the worker against sickness, disease or injury arising out of employment is a key task assigned to the ILO in the preamble of its constitution.

The ILO has generated such hallmarks of industrial society as the eight hour working day, maternity protection, child labour laws and a range of policies which promote workplace safety and peaceful industrial relations. The ILO is the international institutional framework which makes it possible to address such issues — and to find solutions which allow working conditions to improve everywhere. The objective is to provide a 'level playing field' for employers and workers alike. Absence of such measures in one country is an obstacle to others in their development.

Although much has been done to improve working conditions and environment, there is virtually no job or occupation that is wholly devoid of risks to the health and safety of workers. A recent ILO estimate indicates that two million workers die each year through work related accidents and diseases — more than 5000 every day — and for every fatal accident there are another 500–2000 injuries, depending on the type of job.

Protection of workers against exposure to radiation falls naturally within the scope of the ILO's programme of action on occupational safety and health. In June 1960, the International Labour Conference adopted the Convention concerned with the Protection of Workers against Ionizing Radiation (No. 115) and its accompanying Recommendation (No. 114). The Convention applies to all activities involving exposure of workers to ionizing radiations in the course of their work and provides that each Member of the ILO that ratifies it shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate measures. The ILO–OSH 2001 Guidelines of Occupational Safety and Health Management Systems and the ILO Encyclopaedia of Occupational Health and Safety are good examples of such codes and information directly relevant to radiation protection.

The ILO also uses, in a co-ordinated manner, the various means of action available to it to provide support and services to governments and employers' and workers' organizations in drawing up and implementing programmes for the improvement of working conditions and environment. These activities are based on knowledge and experience gained at the international level and advocate the fundamental principles, values and rights embodied in ILO Conventions, Recommendations and Resolutions adopted at the annual International Labour Conference.

This Conference provides a good forum in which to exchange successful experiences in fighting against workplace hazards and risks and to share lessons on how tragedy could happen if safety and health measures were not properly applied. Our task is to promote practical approaches and to assist countries in their efforts to extend occupational safety and health to all workers exposed to ionizing radiation.

Working with radiation can, in some cases, be dangerous to the safety and health of the worker. Radiation work can be highly hazardous when prevention principles are not applied, where protective measures are not taken and when safe work practices are not used because of poor management, or a lack of knowledge, training or assigned accountability and responsibility.

Protection of workers against radiation requires a multidisciplinary approach. In this connection, intersectoral co-operative activities are particularly useful in the avoidance of duplication of efforts and in the efficient use of resources. More importantly, the involvement and participation of all relevant parties, such as the departments of nuclear energy, health, labour, environment and education, as well as research institutions, professional societies, industries, employers', workers' and other non-governmental organizations in the entire process of radiation protection are vital to the success of any radiation protection programmes.

During the course of this Conference there will be many presentations which will provide useful insights on how we could better the protection of workers against exposure to ionizing radiation. Practical measures should be developed and carefully implemented to solve workplace radiation protection problems in contrast to debating issues of only academic value. I understand that as a part of the programme for this Conference, recommendations will be made at the end of the meeting which will guide the future actions of the IAEA and other co-sponsoring organizations as well. I hope that the completion of the Conference will be the start of concrete actions to improve and strengthen the protection of workers against all hazards including ionizing radiation in the workplace. This is also the goal of the ILO's SafeWork Programme.[1]

Finally, I would like to state that it is rewarding to see that international co-operation in occupational radiation protection is developing rapidly and that many non-governmental organizations are playing an active role. Therefore, I would like to congratulate the IAEA for organizing this timely international Conference. I cannot end without extending my gratitude to our gracious host the Swiss Federal Office of Public Health and its staff for their excellent arrangement and great support to the organization of the Conference.

I wish you every success for fruitful deliberations that will eventually bring valuable benefits for the future safety and health of the people at work all over the world.

[1] For further information see: http:\www.ilo.org/safework.

OPENING ADDRESS

J. Naegele
European Commission,
Luxembourg

On behalf of the European Commission (EC), the Directorate General of Environment and Director S. Kaiser, I am pleased to welcome you to this important International Conference on Occupational Radiation Protection. I first want to express our thanks to the Swiss Government and the International Labour Organization (ILO) for inviting us, to the IAEA for its initiative, and to the World Health Organization and the OECD Nuclear Energy Agency for their support.

This Conference really provides a very timely opportunity to initiate a new debate on the future direction of occupational radiation protection. It will help focus attention on the roles that national regulators, nuclear and non-nuclear industry, as well as transport, research and education will play in implementing the most recent international and national provisions on the radiological protection of workers.

Euratom, the European atomic energy community, has already defined legal responsibilities for radiation protection within the European Union (EU) and therefore has a keen interest in this Conference and its results. As you know, the EU places particular emphasis on nuclear safety and radiological protection. Therefore, it has actively sought to strengthen international health and safety regulations to enhance radiation protection in general and in the occupational sector in particular.

The importance of having appropriate and effective radiation protection policies cannot be overemphasized. Exposure to ionizing radiation can lead to detrimental health effects in humans and there is an obligation on each government to ensure that the highest standards of safety and radiological protection are employed.

These subjects will be discussed — hopefully intensively — over the next few days by the experts. The provisions of the most recent international and European recommendations and regulations will profoundly influence radiological protection efforts worldwide and will represent a significant step forward in the radiation protection of workers.

All of you here will be aware of the major contribution that the EC has made to push discussions in this field, including those that will take place at this important Conference. I am pleased to see that the ILO is committed to continuing its support to the international radiation protection community as it prepares to put the most recent scientific information into operational practice. This is the most important and probably the toughest part of the entire process.

I invite the responsible representatives in this field to contribute to a constructive exchange of information and experience and to put all their efforts into the development of practical — I want to emphasize this — solutions, which are acceptable to all involved.

The EC services will do their best to make this Conference a successful step forward in order to meet this challenge. So I would like to wish all participants every success in this process.

OPENING ADDRESS

R. Helmer
World Health Organization,
Geneva

It is my great pleasure to address this eminent gathering of scientists on behalf of Dr. Brundtland, the Director General of the World Health Organization (WHO). The WHO welcomes the initiative taken by the organizers to bring together experts from around the world on the issue of protecting workers from an important health hazard. In actual fact, we enjoy long standing working relations with both the IAEA and the International Labour Organization (ILO). Similarly, we are sharing concerns and activities on a number of public health issues with the Swiss Government. Occupational radiation protection is now adding a new dimension to this co-operation.

The public health mission of the WHO has been reinvigourated by Dr. Brundtland in four strategic directions:

(1) Reducing excess mortality, morbidity and disability;
(2) Reducing risk factors to human health;
(3) Developing equitable health services;
(4) Promoting an effective health dimension to social, economic, environmental and development policy.

This latter goal is of particular relevance to workers' health and to what happens at the World Summit on Sustainable Development currently being held in Johannesburg.

At this very moment the WHO is in the last stages of preparing the World Health Report 2002 which will contain a comprehensive assessment of key risk factors to health. This report will confirm the magnitude of the global burden of disease due to occupational exposure to risks, at a mortality level of well over one million per year. Key occupational risk factors considered are carcinogens, particulates, injuries, ergonomic factors, stress and the special risks which health care workers are confronted with by the very nature of their work. Estimation of the global burden of disease due to ionizing radiation exposure will be undertaken next.

The occupational health programme of the WHO is planned and implemented in close co-operation with the ILO. Task forces are dealing with subjects such as health promotion, health care workers, small enterprises and the informal sector, silicosis elimination and forming an intensive partnership in Africa. Implementation is achieved through a worldwide network of more than 50 collaborating centres.

Co-operation with the IAEA is guided by a basic agreement which dates from as early as 1959. The WHO is a signatory to the two international conventions, on early notification and on assistance in the case of nuclear and radiation accidents and emergencies. It also co-sponsors the International Basic Safety Standards and deals with the application of radiation techniques in food preservation and medical diagnosis.

In light of the its public health mandate, the WHO could not emphasize better the notion presented in the Announcement and Call for Papers to this Conference which postulates that "the radiation protection programme should be established and managed in co-ordination with other health and safety disciplines, such as industrial hygiene and industrial safety."

In order to better respond to health issues related to ionizing, and also to non-ionizing, radiation, the WHO has recently created a new unit entitled Radiation and Environmental Health. The protection of workers in a variety of occupational situations against exposure to ionizing radiation is one of the areas of work for this unit. More details about the WHO's activities are given in a paper presented by L.I. Kheifets and M.H. Repacholi from this unit in the Background Session.

Finally, I do wish your Conference every success. In sharing the same opening date with the 'mega' event in the Johannesburg, you are demonstrating that the grand agenda on sustainable development would remain an empty shell if it were not to be filled with concrete action for the one half of the world's population that are members of the global workforce.

OPENING ADDRESS

K. Shimomura
OECD Nuclear Energy Agency,
Paris

I would like to welcome you on behalf of the OECD Nuclear Energy Agency (OECD/NEA) to this important International Conference on Occupational Radiation Protection: Protecting Workers against Exposure to Ionizing Radiation, which is held in co-operation with the OECD/NEA. The programme promises an interesting meeting, and your support will, I am sure, lead to useful results.

To give you some background information, let me briefly introduce the OECD/NEA and its Committee on Radiation Protection and Public Health (CRPPH).

The OECD/NEA was established in 1958 as a semi-autonomous body of the Organisation for Economic Co-operation and Development (OECD), and currently includes 28 Member countries from Europe, North America and the Pacific area. The OECD/NEA is organized through a Steering Committee for Nuclear Energy under the OECD Council and performs its technical programme through seven standing technical committees and a data bank. The CRPPH organizes information exchange amongst senior policy makers, regulators, and senior representatives of research and development institutions from Member countries and relevant international organizations, in order to harmonize views on important radiation protection issues. The cross-party representation of industry, safety authorities and governmental policy bodies makes the CRPPH a uniquely placed international forum.

One of the long-standing activities of the OECD/NEA in the field of occupational exposure concerns the Information System on Occupational Exposure (ISOE), which was initiated in the 1990s and is now managed by a Joint (OECD/NEA)–IAEA Secretariat. Since its official start in 1992, the ISOE has become a unique worldwide programme for the protection of workers in nuclear power plants, as well as a forum for discussing occupational exposure management issues, and has the world's largest database on occupational exposure attributable to nuclear power plants. Further details of the ISOE programme will be given in a paper presented by B. Breznik (ISOE) later during this Conference.

In addition to this long term programme in worker protection, the (OECD/NEA)–CRPPH offers a forum of senior radiation protection experts to discuss upcoming issues in occupational radiation protection. The discussed issues often lead to short term follow-up activities such as the survey on national practices in worker compensation, which was undertaken in 2001.

The programme of the CRPPH also includes various other activities, which are not directly related to occupational radiation protection but which will certainly have an impact on the protection of workers.

The CRPPH has, for some time now, pursued a dialogue with the International Commission on Radiological Protection (ICRP) on the system of radiation protection. With Prof. R. Clarke's proposal for a future system of radiological protection, the ICRP opened the discussion to the interested community and began the process of developing new recommendations. The CRPPH goal is to ensure that a consensus on directions for improvement is reached among radiation protection experts from national regulatory authorities, and that this consensus is taken into account during the development of new approaches and international recommendations. This will include — through the ISOE — a discussion with radiation protection practitioners in nuclear installations who are investigating the implications of any new recommendation on the protection of workers.

As part of the revision of the current system of radiological protection, a system for the radiological protection of the environment is currently being developed and will be integrated with the general system. The OECD/NEA decided to organize, in collaboration with the ICRP, a series of three forums to promote and establish a process to assist the development of national policies and an international consensus for radiological protection of the environment.

In support of the ongoing evolution of the system of radiological protection, a discussion on strategies with respect to radioactive effluent releases from nuclear installations in normal operation has been launched. Although radioactive effluent releases from nuclear installations have been reduced in recent years, they are still subject to discussion. The demand for further reductions is generally driven by societal concerns about the protection of the environment. The CRPPH Expert Group on the Implications of Effluent Release Options started work on identifying existing options for routine release of low level radioactive substances from nuclear installations with the objective of analysing their implications. An important issue in this respect is the potential risk transfer from the general public to workers in nuclear installations.

Finally, I would like to mention the CRPPH efforts to better understand the experiences and processes of involving stakeholders in radiological protection decision making. The first and second OECD/NEA Villigen workshops were hosted by the Swiss Federal Nuclear Safety Inspectorate in 1998 and 2001 respectively, and were key steps in developing the present-day's general recognition of the importance of stakeholder involvement in some difficult situations. The third Villigen workshop is in the process of being organized by the OECD/NEA and will take place in late 2003.

On behalf of the OECD/NEA, let me thank the Government of Switzerland for its kind offer to host this International Conference on Occupational Radiation Protection. I am looking forward to this interesting Conference.

OPENING ADDRESS

T. Zeltner
Swiss Federal Office of Public Health,
Berne, Switzerland

I am very pleased and honoured — not only to open but also to chair this Conference, and on this occasion I would like to welcome the six additional co-operating organizations as well, namely:

(1) The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR),
(2) The International Commission on Radiological Protection,
(3) The International Commission on Radiation Units and Measurements,
(4) The International Electrotechnical Commission,
(5) The International Radiation Protection Association, and
(6) The International Society of Radiology.

This Conference is fully dedicated to the protection of workers all around the world against exposure to ionizing radiation. According to the latest UNSCEAR report, there are 11 million people who are occupationally exposed to ionizing radiation, and this number is still increasing. But fortunately, a downward trend regarding the exposure to ionizing radiation of several groups of workers can be observed.

With the publication in 1996 of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, a sound basis for the protection of the workers has been established. However, there is still a lot to do with regard to their translation into national legislations.

I would like to remind delegates of the objectives of the Conference, which are to:

(a) Foster the exchange of information on current issues related to the exposure of workers to ionizing radiation in the course of their work;
(b) Formulate recommendations regarding measures to strengthen international co-operation in occupational radiation protection;
(c) Address the issue of establishing occupational radiation protection standards and providing for their implementation;
(d) Focus on a number of specific problems, inter alia, the complex issue of controlling occupational exposure to natural sources of radiation.

We would like to thank the authors for contributing numerous, very interesting papers. These papers have already been distributed and the main findings will be presented by the rapporteurs.

In addition to the opening addresses of the international organizations, the Conference will comprise:

(a) Background session.
(b) Briefing session.
(c) Topical sessions comprising:
  (i) Keynote presentations,
  (ii) Rapporteur summaries,
  (iii) Discussions.
(d) Round table discussions.
(e) Chairperson summaries.

This Conference is the starting point for several future activities. I am convinced that by the end of the Conference, we will have a set of findings and recommendations which will be a solid basis for the future work. The follow-up actions of the participating international organizations should end up in an action plan for future activities in order to enhance occupational radiation protection.

I would like to thank the Conference Secretariat, the Scientific Programme Committee and the Organizing Committee for the enormous effort expended and the excellent work performed in preparing for this Conference.

SCIENTIFIC AND ORGANIZATIONAL BACKGROUND WITH REGARD TO OCCUPATIONAL RADIATION PROTECTION

(Background Session)

Chairperson

T. ZELTNER
Switzerland

THE ROLE AND ACTIVITIES OF THE ILO CONCERNING THE RADIATION PROTECTION OF WORKERS (IONIZING RADIATION)

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Abstract

The 1984 International Labour Conference Resolution concerning the improvement of the working conditions and the environment laid down the fundamental objectives and principles on which the Infocus Programme on Safety and Health and the Environment (SafeWork) of the International Labour Organization (ILO) is based. The protection of the worker against ionizing radiations falls naturally within the scope of this programme which uses, in a co-ordinated manner, the various means of action available to the ILO to give governments and employers' and workers' organizations the necessary help in drawing up and implementing programmes for the improvement of working conditions and the environment. These include international standards in the form of conventions and recommendations, codes of practice, dissemination of information through, for example, the International Safety and Health Information Centre and technical co-operation activities. In June 1960, the International Labour Conference adopted Convention No.115 and recommendation No.114 concerning the protection of workers against ionizing radiations. Convention No.115, which provides that each Member of the ILO ratifying it shall give effect to its provisions by means of laws, regulations, or other appropriate methods, has been ratified by 47 countries. There has been a long standing history of efficient interagency co-operation on radiation protection and 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 International Basic Safety Standards and Safety Fundamentals at both international and national levels.

1. INTRODUCTION

The protection of the worker against sickness, disease and injury arising out of employment is one of the tasks assigned to the International Labour Organization (ILO) in the words of the Preamble of its Constitution. Over the years, the ILO concern for protection of the worker has evolved to assume a broader coverage of the fundamental objectives embodied in the ILO Constitution and the Declaration of Philadelphia. The 1984 International Labour Conference Resolution concerning the improvement of the working conditions and the environment laid down the following principles:

(a) Work should take place in a safe and healthy environment;
(b) Conditions of work should be consistent with workers' well-being and human dignity;
(c) Work should offer real possibilities for personal achievement, self-fulfilment and service to society.

On the basis of the above fundamental objectives and principles, the Infocus Programme on Safety and Health at Work and the Environment (SafeWork) of the ILO aims to increase in Member States the capacity to prevent occupational accidents and work related diseases and improve the working conditions. In pursuing this aim, SafeWork uses as a means of action the development of international labour standards and the formulation of guidance, the provision of technical advisory services (including technical co-operation activities) and the dissemination of information through its publications. In the process, the work of SafeWork promotes productive and remunerative employment in a healthy environment, and as such provides a major contribution to poverty alleviation, worker protection and sustainable development.

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, cover 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 2001, 184 conventions and 192 recommendations were adopted. Almost half of these instruments relate directly or indirectly to occupational safety and health. Conventions and recommendations relevant to occupational radiation protection include Convention No. 115 and Recommendation No. 114 which deal specifically with the protection of workers against radiation (ionizing).

Conventions are comparable to multilateral international treaties; they are open to ratification by Member States and, once ratified, become binding obligations. A government that has ratified a convention is expected to apply its provisions through legislation or other appropriate means as indicated in the text of the convention. The government is also required to report regularly on the application of ratified conventions. The extent of compliance is subject to examination by ILO machinery. Complaints about alleged non-compliance may be made by the governments of other ratifying States or by employers' or workers' organizations, and procedures exist for investigating and acting upon such complaints. Conventions that have not been ratified have the same value as recommendations.

Recommendations are intended to offer guidelines for action by Member States. Often, a particular recommendation will elaborate upon the provisions of a convention on the same subject. Member States have certain important procedural obligations in respect of recommendations, namely, to submit the texts to their legislative bodies, to report on the action resulting therefrom, and to report occasionally at the request of the governing body on the measures taken or envisaged as giving effect to the provisions, but no specific substantive obligations are entailed.

ILO standards have exerted considerable influence on the laws and regulations of Member States. Many texts have been modelled on the relevant provisions of ILO instruments. Drafts of new legislation or amendments are often prepared with ILO standards in mind so as to ensure compliance with ratified conventions or to permit the ratification of other conventions. Trade unions use ILO standards to support arguments in bargaining and in promoting legislation. Governments frequently consult the ILO, both formally and informally, about the compatibility of proposed legislative texts with international labour standards.

Further guidance is provided in codes of practice to be used as reference work by anyone in charge of formulating detailed regulations or responsible for occupational safety and health. They are also drawn up with the objective of providing guidance to those who may be engaged in the framing of occupational safety and health programmes. Codes of practice are adopted by meetings of experts and their publication is approved by the ILO Governing Body. Codes of practice are not intended to replace national laws, regulations or accepted standards. The codes of practice also offer guidelines to employers' and workers' organizations. Their provisions should be read in the context of conditions in the country proposing to use this information and the scale of operation involved. More than twenty codes of practice have been drawn up so far, covering various branches of economic activity or specific risks.

In 1987, the ILO published a code of practice on radiation protection. Subsequently, and with a view to establishing basic requirements for protection against the risks associated with exposure to ionizing radiation and for the safety of radiation sources that may deliver such exposure, six international organizations[1] jointly developed and co-sponsored the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS). The BSS were published by the IAEA in 1996 and represent unified requirements and guidance which are common to the six sponsoring organizations.

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[1] Food and Agricultural Organization of the United Nations (FAO), IAEA, ILO, OECD Nuclear Energy Agency (OECD/NEA), Pan American Health Organization (PAHO), World Health Organization (WHO).

Dissemination of information is a major means of action of the ILO as regards occupational safety and health. Three major complementary tools should be mentioned: the ILO Encyclopaedia of Occupational Health and Safety, 4th edition, 1998 (comprising 4 volumes with contributions from some 1000 authors from 50 countries); the International Occupational Safety and Health Information Centre; and the International Occupational Safety and Health Hazard Alert System which disseminates rapidly, through a worldwide network, scientific and technical information on newly discovered or suspected occupational health hazards.

The ILO also has a number of other means of disseminating information such as the publication of its Occupational Safety and Health Series and the organization of scientific and technical meetings, congresses and symposiums.

Technical co-operation activities to protect the life and health of workers are very wide, ranging from the technical backstopping of the multidisciplinary teams and 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 objectives of the ILO's programmes of activities in the field of occupational safety and health aim essentially at:

(a) Reducing the number and seriousness of occupational accidents and diseases;
(b) Adapting the working environment, equipment and work process to the physical and mental capacity of the worker;
(c) Enhancing the physical, mental and social well-being of workers in all occupations;
(d) Encouraging national policies and programmes of Member States and supplying appropriate assistance.

The objective of the ILO SafeWork programme is to assist countries in designing and implementing national programmes supported by cost effective measures and activities conducive to achieving a significant reduction in occupational accidents and diseases and adverse effects on the environment.

The protection of the worker against ionizing radiations falls naturally within the scope of ILO's programme of action on occupational safety and health which uses, in a co-ordinated manner, the various means of action available to the ILO to enable it to give governments and employers' and workers' organizations the necessary help in drawing up and implementing programmes for the improvement of working conditions and the environment.

2. REVIEW OF PAST ACTIVITIES

Already in 1934, the ILO adopted an international instrument providing that persons sustaining occupational injuries caused by ionizing radiations would receive compensation. Convention No. 121 (1964) concerns benefits in the case of employment injury and includes, under its Schedule 1, compensation for diseases caused by ionizing radiations.

In 1949, the ILO published what is probably one of the first sets of practical international standards on radiation protection which were incorporated into the 'Model Code of Safety Regulations for Industrial Establishment'. These provisions were revised and considerably extended in 1957 and were incorporated as Part II in the ILO Manual of Industrial Radiation Protection. Other parts of this manual consisted of guides on radiation protection in industrial operations, particularly concerning the use of industrial X ray and gamma ray radiography and fluoroscopic equipment and the use of luminous compounds.

In June 1960, the International Labour Conference adopted Convention No. 115 and Recommendation No. 114 concerning the protection of workers against ionizing radiations. Convention No. 115 applies to all activities involving exposure of workers to ionizing radiations in the course of their work and provides that each Member of the ILO which ratifies it shall give effect to its provisions by means of laws or regulations, codes of practice or other appropriate methods. It has been ratified by 47 countries. Convention No. 115 and Recommendation No. 114 lay down basic principles and establish a fundamental framework for the radiation protection of workers. They also contain provisions which concern the protective measures to be taken, the monitoring of radiation and the medical supervision of workers.

Several other international standards adopted by the International Labour Conference are also relevant to the protection of workers against ionizing radiations, notably Convention No. 139 and Recommendation No. 147 concerning the prevention and control of occupational hazards caused by carcinogenic substances and agents, as well as Convention No. 148 and Recommendation No. 156 concerning the protection of workers against occupational hazards due to air pollution, noise and vibration in the working environment.

There are a number of instruments which establish the general framework and institutional arrangements for the protection of workers against occupational hazards in general. 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.

The ILO published jointly with IAEA a Code of Practice on Radiation Protection in the Mining and Milling of Radioactive Ores which was revised in co-operation with the WHO in 1983, the revised text being published by the IAEA on behalf of the three sponsoring organizations. This publication is currently being updated and expanded and will be published by the IAEA as a joint IAEA–ILO Safety Guide.

The IAEA and the ILO co-sponsored a manual on radiological safety in uranium and thorium mines and mills, which was published in 1976 by the IAEA to supplement the above mentioned ILO–IAEA Code of Practice on this matter. The revision of this manual took the form of a guide on monitoring in the mining and milling of radioactive ores published by the IAEA in co-operation with the ILO and the WHO.

The ILO, the IAEA and the WHO co-sponsored a number of symposiums and other meetings. For example, in 1963, a Symposium on Radiation Protection in Mining and Milling of Uranium and Thorium was organized by the ILO and the French Atomic Agency Commission in co-operation with the WHO and the IAEA. In 1983, the ILO co-sponsored a seminar organized in Gabon by the IAEA on the same subject for developing countries in Africa. A joint IAEA–ILO technical advisory mission took place in Niger in 1991. In 1992, the ILO and the WHO co-operated with the IAEA in a joint mission to Namibia with the purpose of making an in-depth assessment of radiation protection in uranium mining and milling.

Together with the IAEA and the WHO, the ILO has taken part in the production of a number of guides published by the WHO on radiation protection in hospitals and general practice which are currently being revised. A safety report on the health surveillance of occupationally exposed workers has been published by the IAEA[2] under the auspices of the three organizations; its previous revision was carried out by the IAEA in co-operation with the WHO and the ILO, and was published in the form of a training manual on radiation protection for occupational health physicians.

A publication on mutual emergency assistance for radiation accidents was published by the IAEA in co-operation with the FAO, the ILO and the WHO; it was updated in 1980 with the co-operation of the United Nations Disaster Relief Organization. In 1969, a publication on Planning for the Handling of Radiation

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[2] For further details see Safety Reports Series No. 5, Health Surveillance of Persons Occupationally Exposed to Ionizing Radiation: Guidance for Occupational Physicians.

Accidents (IAEA/ILO/FAO/WHO) was produced and in 1976 a manual on early medical treatment of possible radiation injury, with an appendix on sodium burns, was issued.

The IAEA, the WHO, the ILO and the OECD/NEA co-sponsored the revision of the 1967 edition of the IAEA's Basic Safety Standards for Radiation Protection in the light of the International Commission on Radiological Protection (ICRP) Publication 26 (1977). This revision was carried out by an advisory group of experts, which held three meetings in Vienna in 1977, 1978 and 1980. The revised Basic Safety Standards for Radiation Protection were published in 1982 by the IAEA on behalf of the four sponsoring organizations.

Consequently, the joint IAEA/ILO/(OECD/NEA)/WHO Basic Safety Standards for Radiation Protection (1982 ed.) represent a common basis on which each organization may develop specialized documents according to its own scope of competence and to the specific needs of its Member States. Furthermore, for IAEA operations and operations undertaken with the assistance of the IAEA, the WHO and the ILO, the basic safety standards should be applied in the light of national rules and regulations. The four organizations and the ICRP co-sponsored a topical seminar on application of the Dose Limitation Systems for Radiation Protection in 1979.

The ILO prepared a brochure concerning the relevant provisions of the basic safety standards (1982 ed.) in co-operation with the IAEA and in consultation with the WHO and OECD/NEA. The purpose of this brochure (No. 55 of the ILO Occupational Safety and Health Series) was to present these provisions in simple language, so that it can reach a wide audience and, in particular, all those directly concerned with the protection of workers against ionizing radiations, even if they are not specialists in this field. This publication was submitted as a technical contribution on the basic safety standards by the co-sponsoring organizations at the United Nations Conference on the Peaceful Use of Nuclear Energy which took place in 1986.

A meeting of experts was held in Geneva in September 1986 to revise the ILO Manual of Industrial Radiation Protection. It approved a Code of Practice for the Radiation Protection of Workers (Ionizing Radiations). The purpose of the Code of Practice is to provide guidance on steps to be taken to ensure effective protection of workers against ionizing radiations in the light of new knowledge of radiation protection. In particular, it provides practical guidance for the implementation of the provisions of the Basic Safety Standards for Radiation Protection (1982 ed.) at enterprise level.

In 1989, the ILO published guidelines for the radiation protection of workers in industry (ionizing radiations). These guidelines (No. 62 of the Occupational Safety and Health Series) provide technical information on protection against radiation in specific installations and for specific equipment, in order to assist the competent authority, employers, workers and their organizations, as well as all those concerned with the protection of workers against ionizing radiations. They describe the requirements for the control of exposure to radiation of workers engaged in radiation work with external sources and unsealed sources. More recently, the ILO and the IAEA are co-operating in the preparation of a draft Safety Report on occupational radiation protection in the decommissioning of nuclear facilities.

An International Trade Union Consultative Meeting took place in Vienna in April 1989. It was organized at the initiative of the International Confederation of Free Trade Unions (ICFTU), together with the IAEA and with the participation of the ILO. The meeting called for close co-operation between the ILO and the IAEA with a view to ensuring that trade unions are involved in the development of nuclear safety policy and in the implementation of occupational safety and health standards. Subsequently, the ILO and the IAEA were closely involved in the World Association of Nuclear Operators/ICFTU consultation on Nuclear Safety which was held in Geneva in February 1993.

There has been a long standing history of efficient interagency co-operation on radiation protection which was strengthened by the establishment in 1986 of an Interagency Committee for Nuclear Accident Response, later renamed as the Interagency Committee for the Response to Nuclear Accidents, and by the establishment in 1990 of an Interagency Committee on Radiation Safety (IACRS). The ILO participates in both interagency committees and took an active part in the United Nations Task Force on Chernobyl. The Occupational Safety and Health Branch acts as the ILO focal point for the Emergency Response System established by the IAEA to meet its obligations under the Convention on Early Notification of a Nuclear Accident and the Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency. The ILO participated in the Post-Accident Review Meeting (August 1986) and in the International Chernobyl Project; an overview of the project was published in 1991 by the IAEA as a Technical Report.

The establishment of the IACRS was an important step towards international harmonization of radiation protection and safety. The IACRS was constituted as a forum for consultation and collaboration between international organizations on radiation safety matters. Within the framework of the IACRS, a joint secretariat was established for the preparation of the BSS which would supersede the previous basic safety standards (1982 ed.) and reflect knowledge gained subsequently and developments in radiation protection and safety and related fields.

The unprecedented international effort to draft and review the BSS involved hundreds of experts from the Member States of the sponsoring organizations and from specialized organizations. The meeting of the technical committee that endorsed the BSS in December 1993 was attended by 127 experts from 52 countries and 11 organizations.

The BSS, which were published in 1996, mark the culmination of efforts that have continued over the past several decades towards the harmonization of radiation protection and safety standards internationally. The BSS are jointly sponsored by the FAO, the IAEA, the ILO, the OECD/NEA, the PAHO and the WHO.

The BSS are based on the latest assessments of the biological effects of radiation made by the United Nations Scientific Committee on the Effects of Atomic Radiation and on the recommendations of ICRP Publication 60 and the International Nuclear Safety Advisory Group.

Another parallel development is the compilation of the Safety Fundamentals for Radiation Protection and the Safety of Radiation Sources which are co-sponsored by the same organizations that co-sponsored the BSS. The Safety Fundamentals, which were published in 1996, is a top level publication in the IAEA Safety Series and provides the basis for the requirements in Safety Standards for the control of occupational, public and medical exposures and for the safety of radiation sources. Safety Guides and Safety Practices provide guidance and information on how to implement the requirements.

3. CURRENT AND FUTURE ACTIVITIES

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 is closely associated with the work of the IAEA's Radiation Safety Standards Advisory Committee which is vested with the important mission of reviewing the IAEA's Safety Series documents on radiation protection and safety of radiation sources and the IAEA's programme of work for the preparation of these documents. Within the framework of the IACRS, the ILO and other Member organizations discuss international policies and standards on radiation protection and co-ordinate among themselves radiation protection activities carried out by individual Member organizations.

The ILO has always maintained 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's Task Group on Occupational Exposure and participated in the work of the ICRP Committee which reviewed the document. The general principles for the radiation protection of workers prepared by the task group provided a foundation for the development of a new IAEA–ILO Safety Guide on occupational radiation protection.

With a view to promoting the involvement of labour departments in formulating regulations and establishing systems for radiation protection and control of radiation sources at the regional level, the ILO actively participated in an IAEA

Regional Seminar on the Establishment of a System for Notification, Registration, Licensing and Control of Radiation Sources which took place in October 1997 in Beijing. At the invitation of the Chinese Nuclear Safety Authority, the ILO participated in a Chinese national seminar on the preparation of China's national basic safety standards. This shows that the ILO attaches high importance to the promotional activities at national level on the implementation of the BSS and on the co-operation between the nuclear and labour departments, as well as to the active involvement of workers' and employers' organizations in occupational radiation protection.

For the purpose of avoiding duplication of efforts and allowing for an effective use of resources, the ILO has decided to focus its radiation activities on co-operation with the IAEA and other international organizations in the preparation of a number of publications relevant to the radiation protection of workers. For example, the ILO co-operated with the IAEA in the preparation of three Safety Guides on occupational radiation protection which were published in 1999 by the IAEA. The ILO has been working with the IAEA, WHO and PAHO on a five-volume Manual on Radiation Protection in Hospitals and General Practice.

4. MAIN FEATURES OF ILO ACTION

The protection of workers against ionizing radiations represents a specific aspect of the protection of workers' health which falls within the larger framework of ILO action concerning occupational safety and health and the improvement of the working conditions and environment of all workers. Current ILO activities relevant to the protection of workers against ionizing radiations are of two kinds.

Firstly, a number of ILO activities concern all workers (including radiation workers), such as those relating to the promotion of national policies on occupational safety and health and the development of institutional arrangements for preventive action to protect workers' health.

Secondly, there are activities directly related to the protection of workers against ionizing radiations. Examples of past activities on the radiation protection of workers which were carried out by the ILO itself and by the ILO in co-operation with the IAEA and the WHO and other organizations concerned have already been given. Such activities will continue and it is expected that international co-operation in the field of radiation protection of workers will not only be pursued but strengthened.

OCCUPATIONAL RADIATION PROTECTION
IAEA functions and policies

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Abstract

The paper describes the functions and polices of the IAEA with regard to occupational radiation protection, which in fact reflect the international approach of the United Nations family to this problem. An international regime on occupational radiation protection has been growing on the bases of international legally binding conventions, international standards and international provisions for the application of these standards. The IAEA has been instrumental in establishing a corpus of occupational radiation protection standards that has a long and fructiferous history. The corpus now comprises one set of basic policy fundamentals on radiation protection, one basic international requirement, the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, one basic guide on general occupational radiation protection, and several supporting guides establishing procedures, inter alia, for monitoring for external radiation and for internal contamination. The United Nations Scientific Committee on the Effects of Atomic Radiation provides the global scientific estimates of the biological effects attributable to radiation exposure and the International Commission on Radiological Protection the basic recommendations on radiation protection that are taken into account in the formulation of the international standards. The International Labour Organization (ILO) harmonizes the interests of governments, workers and employers and provides this essential input into the standards. The IAEA establishes the international standards in co-operation with the ILO and other specialized United Nations organizations. The paper finally describes a number of controversial occupational protection issues which are still being discussed internationally and the author considers that the Conference presents an ideal forum in which to tackle these issues and search for a consensual approach to their solution.

1. AN INTERNATIONAL REGIME ON OCCUPATIONAL RADIATION PROTECTION

The IAEA, with its membership of 134 countries, is the only organization in the United Nations family that has a specific statutory function in occupational radiation protection. The IAEA's overall functions are based on three pillars. Two of these originated from President Eisenhower's "Atoms for Peace" proposals — namely, verification of non-proliferation of nuclear weapons, counterbalanced by technology transfer in the peaceful uses of nuclear energy and its by-products. The other pillar, fully independent, reflects the IAEA's functions in radiation protection and safety. Those who formulated the IAEA's Statute created protection and safety functions that are extremely specific and include explicit obligations for the protection of the health of workers against occupational exposure to ionizing radiation.

The IAEA's statutory functions in occupational radiation protection are quite straightforward; the IAEA is expected to (a) establish standards of safety for protection of health, including such standards for labour conditions; and (b) to provide for the application of these standards at the request of any State. Additionally, over the years, the IAEA became entrusted with the servicing of a number of international conventions containing occupational radiation protection undertakings among States parties.

As a result of its statutory and other functions in occupational radiation protection, the IAEA has, for over 40 years, been building up an international occupational radiation protection regime that includes:

(a) International legally binding conventions,
(b) International standards,
(c) International provisions for the application of these standards.

2. INTERNATIONAL LEGALLY BINDING CONVENTIONS VIS-À-VIS OCCUPATIONAL RADIATION PROTECTION

The relevant international legally binding conventions vis-à-vis occupational radiation protection are Convention 115 operated by the International Labour Organization (ILO) and four conventions operated by the IAEA:

(1) Convention on Early Notification of a Nuclear Accident,
(2) Convention on Assistance in the Case of a Nuclear Accident or Radiological Emergency,
(3) Convention on Nuclear Safety, and
(4) Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management [1].

While Convention 115 is specific for occupational safety and the Early Notification and Assistance Conventions contain requirements that indirectly affect occupational protection, the Nuclear Safety Convention and the Joint Convention include specific obligations on occupational radiation protection.

3. THE SYSTEM OF INTERNATIONAL OCCUPATIONAL RADIATION PROTECTION STANDARDS

3.1. An early start

The system of international occupational radiation protection standards is a hierarchical corpus of documents comprising fundamentals, requirements and guides, which has been built by the IAEA over the years. This corpus of standards has a long history — a history of commitment to the protection of workers — one that had a very early start, in 1956, when the IAEA's Statute was approved calling for the establishment of international "standards of safety for protection of health… including such standards for labour conditions." The process for setting up occupational protection standards started fairly soon after and produced a large number of documents related to occupational radiation protection. In 1962, the first standards for radiation protection were issued [1]. They were revised in 1967 [2], which was the starting date for IAEA collaboration with the ILO, whose experts nonetheless had already been working on the standards. Two classical guidance documents on occupational protection have been issued — the first guidance document on the safe handling of radionuclides, issued in 1962 and reissued in 1973 [3, 4] and, in 1962, the first standard for the monitoring of radiation exposure of workers specifying the use of film badges for personnel monitoring [5]. In this manner, 40 years of IAEA history and commitment to occupational radiation protection have been accumulated.

3.2. Expanding system

In 1965, the IAEA introduced standards for radiation protection services [6] which are now recognized worldwide as a basic requirement for occupational monitoring [7]. These standards were revised in 1980 [8]. In the 1960s, the IAEA began recommending ad hoc approaches to the protection of workers in specific situations, for example, at nuclear power plants [9], in conducting hydrological activities [10], or in contaminated environments. Standards for respiratory equipment and protective clothing were already part of the IAEA's menu at that time [11]. In 1968, again jointly with ILO, and this time also with the World Health Organization (WHO), the first recommendations were issued on the medical supervision of radiation workers [12]. In the 1970s, the IAEA entered into the area of occupational protection in mining and milling, once more with the ILO and the WHO, issuing standards that were subsequently revised in 1983 [13]. Radiation protection procedures were issued in 1973 [14]. In 1974, the IAEA issued the first international guidance for the safe handling of plutonium [15]; guidance on neutron generators having been issued in 1973 [16]. In 1976, the IAEA produced the first manual on radiological safety in uranium and thorium mines and mills [17]. In 1978, the IAEA issued the first manual on the early medical treatment of occupational radiation injuries [18].

3.3. A new system of dose limitation

In 1982, a new chapter in the history of labour protection standards started. It was the first time that, jointly with the ILO, the OECD Nuclear Energy Agency and the WHO, the IAEA established the first joint radiation safety standards, which included the new system of dose limitation that the International Commission on Radiological Protection (ICRP) was recommending at the time (as indicated before, prior to that date, the ILO had always been involved in the development of the IAEA occupational protection standards but these standards were not issued jointly) [19]. In quick succession, recommendations on how to apply this new system to mining and milling [20], basic principles for occupational monitoring [21], and new recommendations for the medical handling of accidents were issued [22].

In 1989, for the first time, the IAEA tackled the difficult issue of monitoring of workers in mining and milling [23]. The 1990s saw the emergence of new procedures for occupational protection at nuclear power plants [24], for gamma and electron irradiation facilities [25] and for industry, medicine, research and teaching [26] — all following the new system of protection.

3.4. Optimizing radiation protection

Also in the 1990s, the main change occurred — the one standard that was really crucial for the successful history of occupational protection to date was issued [27]. This was the first international standard on the optimization of protection, a document that implemented the recommendations made in ICRP Publications 37 and 55. This is, without doubt, a long and successful history that brings us to this point today.

3.5. The present situation

The present situation with regard to international occupational radiation protection standards can be summarized as comprising:

(a) One set of basic policy fundamentals on radiation protection, which was issued together with the ILO and four other international organizations in 1996 [28];
(b) One basic international requirement, the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS), which again were issued jointly with the ILO and four other international organizations [29];
(c) One basic guide on general occupational radiation protection [30];

(d) Several supporting guides establishing procedures, inter alia, for monitoring for external radiation [31] and for internal contamination [32].

All of these standards have been co-sponsored by the ILO.

4. BUILDING UP THE INTERNATIONAL STANDARDS

The international system of occupational protection standards is built up thus:

(a) The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) provides the global scientific estimates of the biological effects attributable to radiation exposure; this is done at the highest possible level within the United Nations system, namely, the level of the United Nations General Assembly (see in these Proceedings the paper entitled UNSCEAR's Contribution to Occupational Radiation Protection).
(b) The ICRP, a non-governmental professional organization established in 1928 by the Congress of Radiology, provides the basic recommendations on radiation protection that, by mandate from the IAEA's Board of Governors, are taken into account in the formulation of the international standards.
(c) The ILO harmonizes the interests of governments, workers and employers and provides this essential input into the standards.
(d) The IAEA establishes the international standards in co-operation with the ILO and other specialized United Nations organizations.

The combined efforts of all these international partners have produced an international approach to the international standards, which a large majority of States have adopted (either de jure or de facto) and apply in practice.

4.1. The international approach: Practices and interventions

The international approach forming the basis of the standards has evolved over the years and divides the possible situations of applicability into two categories:

(1) *Practices* or new activities, for which it provides prospective protection rules for the a priori protection design;
(2) *Interventions* in de facto situations, for which it provides retrospective protection rules involving a posteriori protective actions.

The approach is slightly different for workers and for members of the public.

4.2. Occupational and public exposures

In the case of prospective situations that are expected to affect members of the public, what is controlled is the additional dose to the background dose that the public is expected to receive as a result of the introduction of a new activity (see Fig. 1).

On the other hand, for existing situations, the aspect being controlled rests on the decision of whether or not to intervene, given a pre-existing radiation dose and how much this pre-existing dose has to be averted (see Fig. 2).

However, occupational protection situations are rather peculiar and should not be confused with situations for protection of the public. The first peculiarity is that — in international parlance — occupational protection refers to protection against *all* exposures that an identified worker incurs in the course of their work (including those incurred during transport from domicile to workplace), as is clearly established in labour conventions that are much older than those of the United Nations system. It should be noted that, conversely, as indicated previously, for members of the public the exposures against which protection applies are purely the *additional* exposures

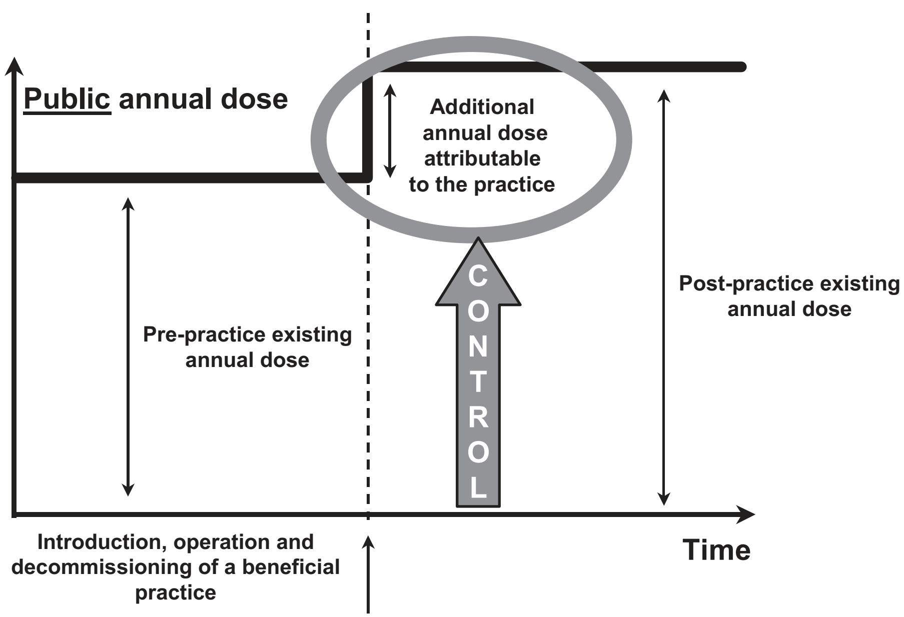

FIG. 1. For practices the expected additional dose is to be controlled.

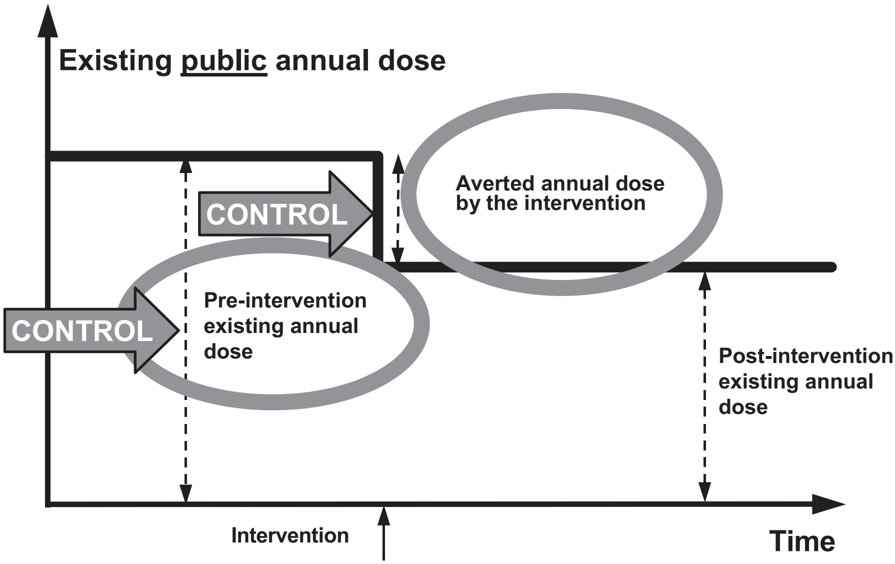

FIG. 2. For intervention the control is on the existing dose and on the dose averted.

attributable to a specific source or group of sources. Moreover, in the public case, protection does not apply to identifiable members of the public but to a critical group represented by an idealized individual.

The second peculiarity (derived from the first one) is that occupational exposure has two components, one that is basically unamenable to control by the employer — such as exposure due to cosmic rays — and another that is conceptually amenable to control by the employer (see Fig. 3). The unamenable to control component might in all logic be excluded from protection standards. The problem is that, with a few exceptions, such as exposure to radon, there is no international agreement on what exposures are to be included in (or excluded from) this component. While most of the occupational exposure is amenable to control and should conceivably be controlled by the employer, only part of it is attributable to the usually 'artificial' radiation sources that bring profit to the employer, the other part being due to 'natural' exposure that is not necessarily related to the type of work. This latter peculiarity of occupational exposure creates a dilemma that the author hopes will be discussed in full at this Conference.

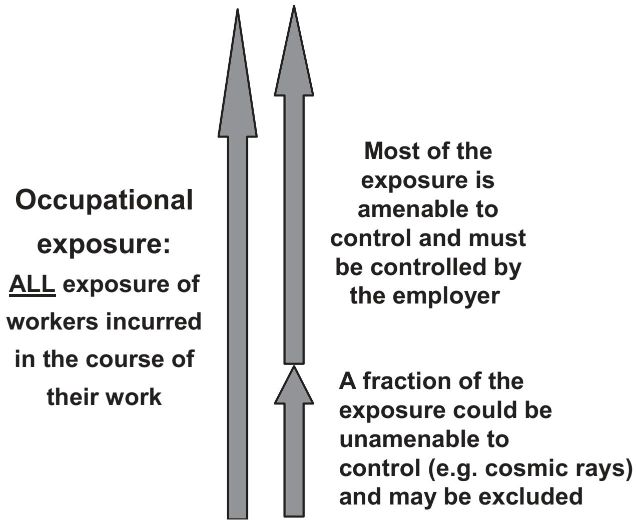

FIG. 3. Occupational situations are peculiar.

4.3. Applying occupational protection

In summary, the situation regarding occupational exposure is that represented in Fig. 4. Workers are always exposed to unamenable to control doses that are expected to be excluded. The dose rate at which the unamenable to control dose is delivered is assumed to be more or less constant (except for itinerant workers who may go from high natural radiation areas to low natural radiation areas or vice versa). In addition, workers are exposed to amenable to control doses, which are expected to be *restricted*, reduced to as low as reasonably achievable levels and individually monitored. Applying occupational protection really means restricting, reducing and monitoring these amenable to control doses through the application of occupational protection measures. The remaining dose corresponds to the so-called ‘occupational exposure’, which is the dose that is committed by a worker as a result of the worker’s occupation, after applying the occupational protection measures.

4.4. Occupational dose restrictions

The international dose restrictions on occupational exposure are shown in Fig. 5. The dose limit is 20 mSv/a, with a special allowance of 50 mSv for a single year or, in very exceptional conditions that are specified in the international standards, of 100 mSv.

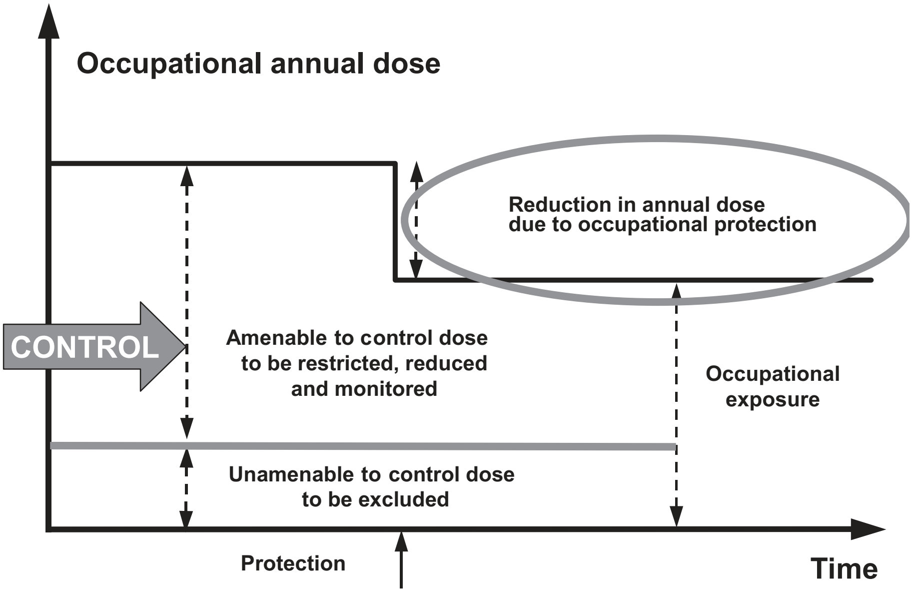

FIG. 4. The situation of occupational exposure.

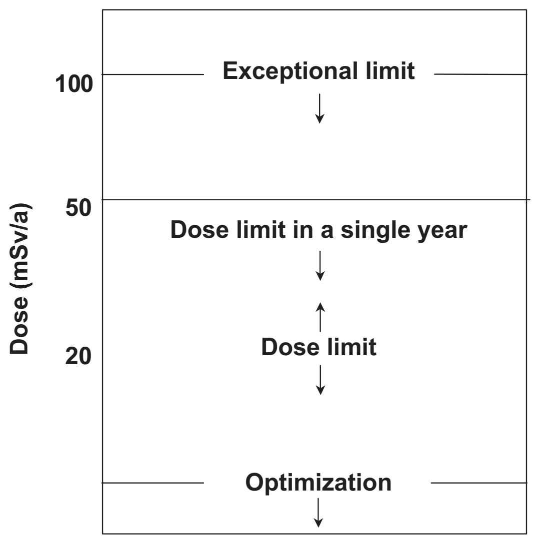

FIG. 5. The international restrictions on occupational exposure.

4.5. Committed versus incurred exposures

One important condition, which is obvious within the profession but which unfortunately is not properly covered in many national legislations, is that the occupational dose to be restricted is the dose that is *committed*, rather than the dose that is *incurred*, by the worker in a year of work. For activities involving long lived radionuclides the difference between the committed and the incurred dose can be more than one order of magnitude.

Figure 6 shows the dose that a worker will receive over one year of work. As the worker incorporates radionuclides into the body as a result of the occupation, he/she will continue to receive doses over the years resulting from that incorporation during that one year of work. If he/she works for two years under the same conditions, the dose to be received will be higher, as shown in Fig. 7. In equilibrium, the dose to be received will be much higher, as shown in Fig. 8, and it is to this dose that the restrictions apply. In summary, it is the summation of the occupational doses incurred (A+B+C+D, etc.) over the years that has to be controlled; the summation time being 50 years in international standards. This is obvious for the audience of experts at this Conference, but the author has learned that, to his surprise, there are national legislations where this principle still does not apply.

5. INTERNATIONAL PROVISIONS FOR APPLICATION OF STANDARDS

International standards are essential, but it is equally important to provide for their application. The IAEA has several mechanisms that allow for application of the standards; mechanisms which it shares with the ILO, namely, providing technical

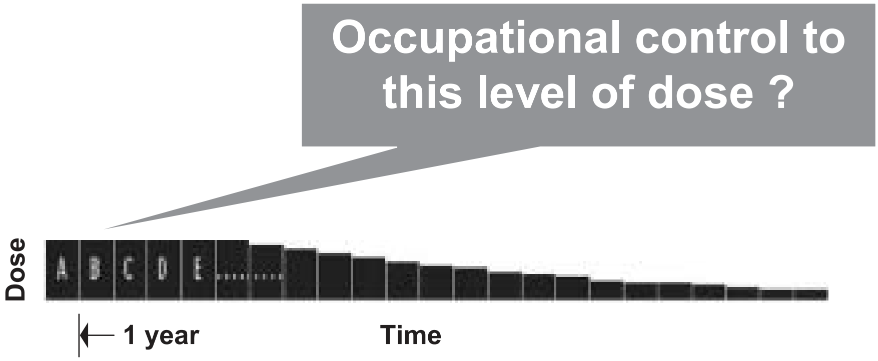

FIG. 6. Annual dose due to one year of occupation.

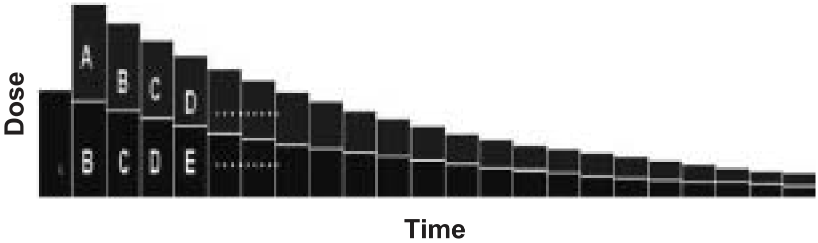

FIG. 7. Annual dose due to two years of occupation.

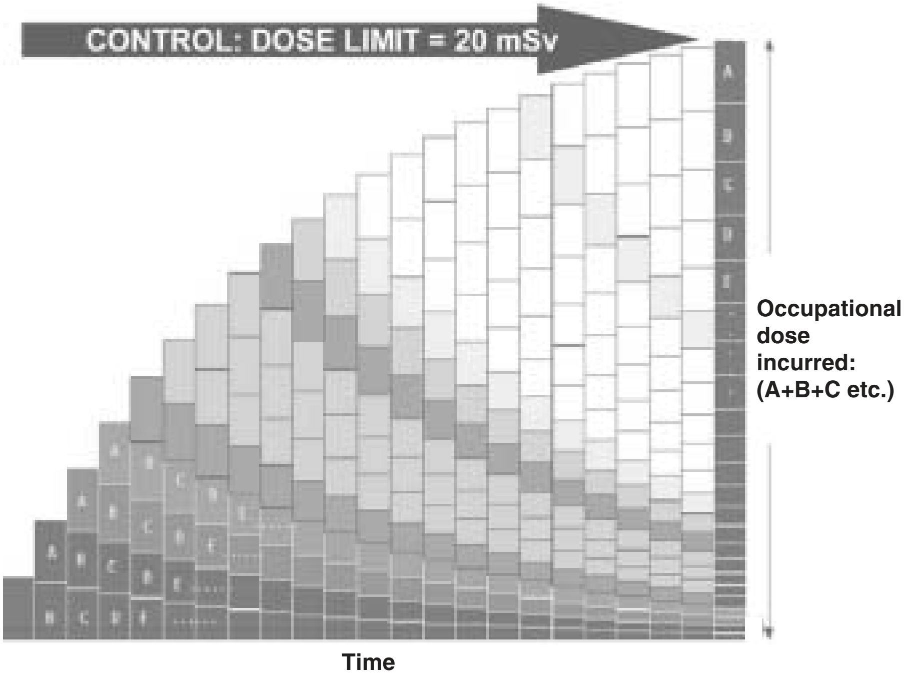

FIG. 8. Dose received at equilibrium.

assistance, fostering information exchange, promoting education and training (at present the IAEA is the largest 'university' in the world educating people in this field), co-ordinating research and development on unresolved issues, and rendering appraisal services — the IAEA places increasing importance on this last mechanism (see Fig. 9).

6. OUTLOOK

A number of controversial occupational protection issues are still being discussed internationally. This Conference presents an ideal forum in which to tackle these issues and search for a consensual approach to their solution. The issues include the following:

(a) The ICRP is working towards new recommendations that could affect the current occupational radiation protection regime. The ICRP's Scientific Secretary, J. Valentin, will discuss the forthcoming ICRP recommendations and will surely welcome any Conference input into their elaboration.

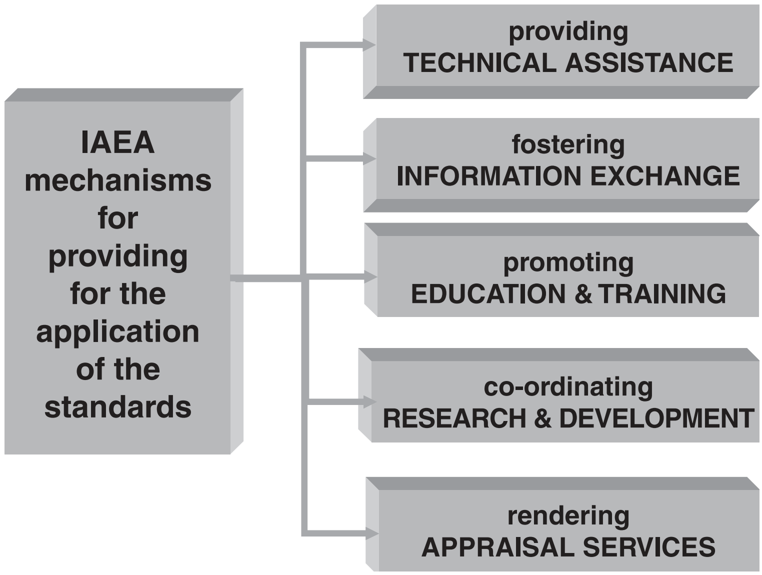

FIG. 9. The IAEA mechanisms for the application of the standards.

(b) Compliance with current international policy on occupational radiation protection is not globally homogeneous. Many countries around the world have no proper radiation protection infrastructure and, in particular, no occupational radiation protection infrastructure, and this is a serious problem. The IAEA has a technical co-operation ‘model project’ to meet requirements in this area from its Member States. This model project was covering 52 countries and this figure has now been extended to more than 80. However, a large problem remains; more than 50 countries within the United Nations system are not members of the IAEA and do not receive any type of occupational radiation protection assistance.

(c) There is no universal consensus on whether the employers of occupationally exposed workers or the licensees of the radiation sources delivering the exposure hold responsibility for occupational radiation protection. In many cases employers and licensees are the same legal persons, but in some situations they may be different (as in the case of itinerant repair workers). For the international standards it is clear that the responsibility for occupational radiation protection ultimately always lies with the employer, but this basic principle has not been widely respected. However, in much national legislation the licensee, rather than the employer, still has responsibility over occupational protection.

(d) There is no fully universal use of standardized quantities and units. Taking into account that there are international conventions establishing undertakings on occupational radiation protection, homogenous (and comparable) reporting on compliance is a very important issue. However, some major countries still use old fashioned systems of quantities and units.

(e) There are different approaches and legislation around the world on the controversial issue of the protection of pregnant workers.

(f) In many countries there is a famous (or infamous) system of *medical surveillance*, which has become a kind of business for a group of doctors. The issue that clinical diagnosis cannot and shall not be used to verify compliance with occupational radiation protection standards needs further (and perhaps tutorial) action.

(g) One of the more important forthcoming issues is the applicability of current standards to natural exposures. Employers, as already recognized, must control such exposure when feasible. The control of exposure due to radon has been defined precisely, but the control of exposure due to other nuclides has not. Other solutions have been ad hoc and piecemeal. There is a need for a deeper and more coherent policy for addressing this very complicated issue.

(h) The issue of attributability of cancer to occupational radiation exposure is scientifically straightforward but socially dramatic for workers and employers alike in many industries. With the radiation workforce ageing, around a quarter will develop cancer that will probably be attributed to their working life exposure, however low such exposures may be. Again, this is a complicated issue that some countries are solving in an ad hoc fashion.

(i) Finally, there is the controversial issue of the safe termination of practices. A turn in the road is not the end of the road unless there is a failure to make the turn and, certainly, the forthcoming turn for us is the safe termination of practices. We have to admit that we have done very little in our standards on how to terminate practices safely. All the standards are for new activities. Although we are keenly proactive, we have done little for the termination of practices. The termination of practices may bring future exceptions to the positive trends in occupational protection. In fact, currently there is a clearly diminishing trend in the levels of occupational exposure. However, when the average age of facilities grows there will be higher doses and the augmented need to decommission facilities and terminate practices will increase the number of workers and therefore the collective dose. Such a dose increase will not necessarily indicate that occupational radiation protection is failing, but simply that there is more work, and more work means more doses. However, this will be very difficult to explain. The Information System on Occupational Exposure should help us follow the development of this issue.

In October, in Berlin, the IAEA is organizing an international conference on the termination of practices and hopefully this issue will also be discussed at that Conference.

7. EPILOGUE

Some years ago, when, together with colleagues from the Swiss Federal agencies and the ILO, we conceived the idea of convening an international meeting of experts to discuss occupational radiation protection issues, it was never envisaged that it would result in such a successful Conference as this. It is deeply rewarding to see that so many people have shown such interest in the subject and in the many issues that will need to be tackled in the future. It is expected that this Conference will address all the above and other open issues and will propose solutions that could be materialized through an international action plan.

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SCIENTIFIC AND ORGANIZATIONAL BACKGROUND WITH REGARD TO OCCUPATIONAL RADIATION PROTECTION

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Abstract

The starting point of the joint European health policy is the 1957 Euratom Treaty, which puts great emphasis on the protection of workers and the general public against dangers arising from ionizing radiation. New radiation protection legislation is driven by scientific developments, by experience with former legislation or by identification of regulatory gaps. Additionally, new legislation has been initiated after identification of changes in social and industrial structures and after the Chernobyl accident. To ensure a harmonized and sound operational implementation of the new radiation protection requirements, close contact is kept between the European Commission departments active in the radiation protection field and those responsible for operational radiation protection in competent authorities as well as in the working field. This process also identifies the need for new regulations. The European radiation protection policy contributed significantly to the achievements, providing for the present high standards of radiological protection of workers and the general public within the European Union. However, the radiological protection issue cannot be seen as isolated and detached from other developments in our society, which is confronted with major problems, most of which appear from the fact that the different sectors in our society progress and develop at different speeds. This leads to confusion and therefore the subject of radiation protection in industry, education, research and medicine is a multidisciplinary initiative involving different interest groups and specialized services. This activity will continue to be of importance for the next century.

During the last four decades, the European Atomic Energy Community (‘community’) has placed a strong emphasis on the protection of workers and the general public against dangers arising from ionizing radiation. The starting point of this joint European health policy was the 1957 Euratom Treaty. This multinational contract vested the community with far-reaching and long sighted formal and material competence, not only for the promotion of the peaceful use of nuclear energy but also for the protection of the public and the workers against the dangers arising from the use of ionizing radiation. Since 1959, the community has made frequent use of its powers and established, in regular intervals, the centre point of European radiation protection policy — the basic safety standards for the radiological protection of workers and the general public.

It is in the nature of the Treaty that the first basic safety standards of 1959 focused on the protection of nuclear industry workers. Repeated updates over more than 40 years have improved and strengthened the provisions and equalized the protection standards for all categories of workers and also for the public. In this context, the evolving radiation protection policy of the community extended systematically the scope and the application fields of European Union (EU) radiation protection legislation and recognized international conventions in the public health and work areas and in the nuclear sector.

In order to meet this wide range legislative challenge, the Euratom Treaty imposes specific obligations on the EU institutions to follow a strict constitutional procedure. Three steps of the law giving process ensure that European radiation protection legislation is in line with the most recent scientific findings, that it incorporates the experience gained with former and other EU legislation, and that it also reflects the standpoint of the social and economic sectors of our society. In this context, the legal framework foresees that the initiative for issuing new legislation could be taken either by the Member States or by the European Commission (EC). If this initiative is registered, the Treaty obliges the EC to recognize the opinion of the scientific family represented by competent radiation protection and public health experts nominated by the Member States but not acting as their representatives. Following this step, the Treaty also obliges the EC to incorporate the opinions of the social partners, the employees and the industry. Only after these consultations have successfully reached mutual agreement will the third step be taken and proposals for new legislation put on the political 'terrain', or perhaps better stated, on the political 'battlefield', namely, that of the European Parliament and the European Council.

Since 1957, only the EC initiated new radiation protection legislation driven by new scientific developments, by experience with former legislation or by the identification of regulatory gaps. Additionally, new legislation was initiated after the identification of changes in social and industrial structures and unfortunately after the Chernobyl accident.

The obligation of the Member States to communicate to the EC details of every project requiring the adoption of EU radiation protection legislation and the obligation of the community to establish co-operation with international organizations in the nuclear sector form the core instruments of the EC used to gain the necessary information and experience.

The reflection of the scientific content of radiological protection recommendations issued by the International Commission on Radiological Protection (ICRP) and the synchronized time lapse between their publication and the approval of new EU Basic Safety Standards demonstrate the close interconnection between science and legislation in this specific area.

However, the law giving process and the legal adoption are only a halfway step forward. Essential for protecting workers and the public against the dangers arising from ionizing radiation is the harmonized and sound operational implementation of new radiation protection requirements. The close contact between the EC's departments active in the radiation protection field and those responsible for operational radiation protection in the competent authorities as well as in the working field creates the platform for fruitful collaborative work. First hand information from these bodies on the operational status of radiological protection demonstrates to the EC directly the efficiency and the effectiveness of the regulations and shows their trends and developments.

The experience gained during this information exchange process is the driving force in the identification of the need for new regulations. Making a change just for the sake of it is commonplace everywhere in society. During the last four decades, the radiation protection policy of the EU was always oriented towards improving safety standards and towards bridging regulatory gaps by creating the conditions for the reduction of the health risk to workers and the public. The identification of needs resulted in the adoption of the first Medical Exposure Directive in 1984, the Directive on Outside Workers, the Directive on informing the public and, most recently, in a proposal for a Directive on the management of sealed sources.

This health and safety policy now finds itself standing at a crossroads. Within the EU, the Member States have completed or will complete the adoption of the new 1996 Basic Safety Standards. The implementation and integration of the new radiation protection concepts into national regulations, in particular the extension of their scope to workplaces with enhanced levels of natural radiation, and the distinction between practices, work activities and interventions, have caused difficulties. The requirements on dose constraints are even more difficult to incorporate into radiological protection rules because the definition of dose constraints is still under discussion by experts. The concept of clearance and exemption was nearly a throwback to the times of religious wars. On the other hand, the reduction of dose limits was an easy task for the national regulators as was the fulfilment of the new requirements for reporting and authorization. Amongst others, there are still problems with the harmonization of the regulatory control arrangements for consumer products containing radioactive substances.

Another reason for the delays is the more frequent interpenetration of areas regulating radiological activities with those areas regulating non-nuclear practices. Systematically, practices, work activities and interventions are regulated on a national level by transport regulations, social law, workplace safety requirements and sometimes by the norms and safety standards used for industrial activities and products.

Additional to the activities ongoing in the Member States, the EU is confronted with its most important challenge ever — the accession of ten Central and Eastern European countries. These countries have to demonstrate to EU governments that they are, at the foreseen date of entry, in a position to adopt all European legislation within an agreed time-frame.

In the radiation protection area, most of the candidate States will have adopted all EU radiation protection legislation except for some requirements of the Medical Exposure Directive. The operational implementation will surely cause many more problems, mainly as a result of the immediate economic impacts on the national and industrial budgets.

However, the radiological protection issue cannot be seen anymore as being isolated and detached from other developments in our society, which is confronted with major problems and is undergoing deep-rooted changes.

Most of these problems appear from the fact that the different sectors in our society progress and develop at different speeds. The peacemaker is the progress made in science. Its pace is not fast, not a speed, no, but an insane race.

The only sector that can follow the speed of scientific progress is the technological sector, in particular the military and biotechnology areas. The economic sector follows at a much slower rate and risks losing contact.

Completely disconnected from this progress is the political sector. Political decisions are in almost every area antiquated compared with the recent scientific developments.

The difference in the speed of progress between developments in science and advancements in politics also affects radiation protection. As is already known, in 1991, ICRP scientists published new radiological protection recommendations. Now, 11 years later, the politicians and the regulators have still not accomplished their duties and the users of ionizing radiation and other concerned bodies often still do not know in which direction the regulatory train will finally go.

At exactly the same time, the ICRP and other scientists confront the whole radiation protection family with their intention to deliver new recommendations based on the most recent scientific findings.

In light of the above, it is understandable that the public at large, and even the deeper involved parties, are confused. They hear of new scientific developments and they recognize reports of public and workers' health and safety status and compare this with existing, sometimes not even finalized old-fashioned regulations.

Therefore, it should be one of the major tasks of all involved bodies to work towards an acceleration of political decisions, in particular in radiological protection. On the other hand, if radiation protection wants to be accepted by all the involved groups, it must avoid doing actions for their own sake.

However, the EC is aware of the fact that an unequal administrative or financial burden on national radiation protection bodies may create an unwanted economic imbalance and assurance should be provided that strengthened radiation protection requirements are not used for justifying incisive social changes.

The protection of workers against the dangers arising from ionizing radiation is not an isolated subject in workplace safety and worker health politics. It is part of a package of regulatory measures and actions taken in the industrial, social and health policy sectors.

Therefore, the subject of radiation protection in industry, education, research and medicine is a multidisciplinary initiative involving different interest groups and specialized services. It is an activity that will continue to be of importance for the next century.

The EC invites the responsible representatives in this field to contribute to a constructive exchange of information and experience and to put all their efforts into the development of practical solutions which are acceptable to all involved in the occupational radiation protection sector.

The author firmly believes that, through a process of negotiation and discussion, such as that provided by this Conference, we will gain a deeper insight and a better appreciation of the many issues involved in the operational implementation of measures that satisfy international and national occupational radiation protection requirements.

It is not an overstatement to say that the European radiation protection policy has contributed significantly to the achievements by providing for the present high standard of radiological protection of workers and the general public within the EU.

The EC, together with the other European institutions, will continue to co-ordinate combined, scientifically, socially, economically and legally based efforts to support future radiological protection concepts aimed at maintaining and improving the already remarkable level of radiological protection afforded workers and the general public. In this context, the author wishes the Conference every success.

THE WORLD HEALTH ORGANIZATION'S NEW PROGRAMME ON RADIATION AND HEALTH

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Abstract

The World Health Organization (WHO) recognizes the social and economic importance of utilizing ionizing radiation for the benefit of humankind and that exposure to radiation is a natural and unavoidable consequence of living on Earth. However, exposure to radiation, both human-made and natural, can be detrimental to health. Thus, there is a need to balance the benefits from the use of radiation against the risks of consequential exposure, to ensure a net benefit. This need can only be met by developing a sound knowledge of the effects of radiation exposure on health. Thus, in the area of ionizing radiation, as well as in other areas, the WHO is striving to achieve safe, sustainable and healthy human environments, protected from biological, chemical and physical hazards, and secure from the adverse effects of global and local environmental threats. As a directing and co-ordinating authority on international health work within the United Nations system, the WHO evaluates health risks related to radiation exposure and provides advice to national authorities. Ionizing radiation is receiving an increased priority within the WHO.

1. WHO's CORPORATE STRATEGY

The World Health Organization's (WHO's) corporate strategy has been formulated to emphasize:

(a) Development of a strong evidence base,
(b) Development of recommendations for radiation safety standards and protective measures,
(c) Provision of support in case of nuclear or radiological accidents,
(d) Building of national capacity,
(e) Provision of information and education.

Within WHO headquarters, a new Radiation and Environmental Health Unit has been established to deal with the implementation of this strategy in collaboration with the Diagnostic Imaging and Laboratory Technology Team.

WHO activities in radiation and health are performed in collaboration and co-ordination with numerous international and national partners. The WHO has agreements with several international organizations covering collaboration in radiation related activities, the most important of which is that with the IAEA. The WHO–IAEA Basic Agreement (1959) covers areas such as co-operation and consultation, reciprocal representation and exchange of information and documents. In addition, the WHO is a signatory to two international conventions, for which the secretariat is the IAEA. These cover early notification and assistance in the case of nuclear and radiation accidents and emergencies. The WHO works in partnership with the IAEA while maintaining its independence on issues related to the health effects from exposure to ionizing radiation.

The WHO participated in the development of the International Basic Safety Standards on radiation protection, led by the IAEA. The WHO also works with many other international agencies such as the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) administered by the United Nations Environment Programme, the World Meteorological Organization (e.g. nuclear accidents), the International Labour Organization (e.g. occupational health guidance) and the Food and Agriculture Organization of the United Nations (e.g. food irradiation, allowable contamination of radioactive materials in food). An international interagency committee has been established to respond appropriately in case of a large nuclear accident. In addition, the WHO works with its specialized agency on cancer, the International Agency for Research on Cancer (IARC), and with its regional offices, NGOs and collaborating centres to develop a strong and co-ordinated programme.

Public exposure to ionizing radiation originates from cosmic and terrestrial radiations, radioactive substances present in materials, the use of nuclear energy in power generation and from radiation used in medicine, industry and research. The highest contribution to people’s exposure comes from the use of radiation in medicine. Another important contribution comes from radon gas in homes; radon is a radioactive decay product of natural uranium found in most soils. Both of these exposures can be significantly reduced.

Radiation accidents of varying severity occur each year. The majority of such accidents involve exposure of one or several individuals to radioactive sources, or patients exposed to excess radiation levels from inappropriately calibrated radiotherapy equipment. Only exceptionally does it involve accidents in nuclear power installations that threaten large populations in several countries. A large number of significant radiation accidents have occurred and these, along with the radiation resulting from the former testing of nuclear weapons, will continue to expose populations for decades owing to the contamination of huge territories by long lived radionuclides. These accidents have lead to significant death and morbidity and most are preventable. The recent use of depleted uranium munitions in military conflicts has also contributed to environmental radiation exposure.

Applications involving radiation continue to expand. Food in many countries is irradiated to eliminate biological agents, thus prolonging shelf life and contributing to providing food to poor countries. With energy shortages predicted, nuclear power is increasingly seen as a viable option to make up this shortfall, especially since it does not contribute to the greenhouse gases that lead to global warming.

Since the advent of the nuclear age and the use of atomic weapons, people have had a genuine concern about the use of radiation in any form, especially nuclear energy. While the public perceives the risks from radiation exposure as high, the global burden of disease is thought to be relatively low. To date, the global burden of disease from radiation exposure from all sources has yet to be determined. However, the public perception of this issue has placed governments under increasing pressure to have comprehensive radiation protection programmes and to provide sound advice on the use of radiation. It is the WHO's responsibility to ensure that Member States are given the scientific support and advice needed to deal effectively with this issue.

2. STRATEGIC DIRECTIONS

The following global programme areas embody the principles outlined above, namely, that all aspects of detriment should be taken into account where public health is at risk from exposure to ionizing radiation.

2.1. Develop the evidence base for scientific assessment

Numerous radiation exposure situations require rigorous reviews of the scientific literature to provide an assessment of possible health consequences and to identify gaps in knowledge. The WHO also relies on assessments of health effects from environmental radiation made by UNSCEAR.

For some of these assessments, the WHO works closely with IARC. Preparation of IARC monographs represents the first step in carcinogenic risk assessment and involves examination of all relevant information in order to assess the strength of the evidence that certain exposures could alter the incidence of cancer in humans. The second step is quantitative risk estimation of all possible health effects and this is conducted by the WHO. Health risk assessments are made for various exposure situations such as radon in homes, medical applications of radiation or use of depleted uranium. These technical reviews provide the scientific basis for the assessment of the global or environmental burden of disease from radiation.

2.2. Recommendations for health protection

On the basis of recommendations on exposure limits made by the WHO's NGO, the International Commission on Radiological Protection (ICRP) and the International Basic Safety Standards published by IAEA, the WHO develops public health policy and provides guidelines for exposure limits in air, water, food and the environment, as well as support for guidance on the use of radiation in industry, medicine and research.

2.3. Emergency preparedness and assistance

The WHO's response under the Early Notification and Assistance Conventions is the development and management of a network on Radiation Emergency Preparedness and Assistance (REMPAN), as well as the provision of public health advice to national authorities and participation in the UN interagency committee to respond to major accidents.

REMPAN currently consists of 14 collaborating centres for promoting medical preparedness and providing assistance. These centres are located in Armenia, Australia, Brazil, France, Germany, Japan, the Russian Federation, Ukraine, the United Kingdom and the United States of America. This network stands ready to respond to nuclear reactor accidents or activities involving release of radioactive materials, to overexposures due to lost or stolen sources, re-entry of nuclear powered satellites, overexposures from medical and industrial sources and to an increased threat of nuclear terrorism. The centres provide medical assistance and treatment to exposed patients (in collaboration with the IAEA), make information on patient treatment available to network members, develop and maintain updated patient treatment protocols, provide public health advice to keep population exposures as low as can be achieved and provide a forum for lessons learned from accident responses.

2.4. Support for national programme development

The WHO assists national authorities with advice and training to build capacity to deal effectively with the public health consequences of radiation accidents and exposures. Examples of activities where the WHO needs to provide advice and support to national programme development are:

(a) Guidance on allowable concentrations of radioactive materials in air, water and food;
(b) Information on the safety of food irradiated to eliminate biological organisms;
(c) Measures to reduce radiation exposure;
(d) Radiation protection standards for occupationally exposed people.

In many cases, this assistance may be provided by the IAEA through an extensive series of publications and programmes. The WHO does not duplicate this assistance, but assists ministries of health with appropriate information on radiation induced health effects and on how to play an appropriate role in the protection of public and occupational health.

2.5. Information and education

The WHO's Radiation Unit develops radiation training programmes in association with the IAEA and other partners, provides information through all available media (publications, CD-ROMs, web, videos, etc), and acts as a medium for information exchange.

Through its web site[1], fact sheets, peer reviewed publications and its response to numerous enquiries, the WHO strives to provide accurate and up to date information on radiation issues to all interested people. In addition, it conducts training courses that are based on training materials on radiation risks of low doses of ionizing radiation and training materials on medical monitoring of radiation victims.

[1] The web address is http://www.who.int/peh/radiation.

OCCUPATIONAL RADIATION PROTECTION AT THE OECD NUCLEAR ENERGY AGENCY

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Abstract

The OECD Nuclear Energy Agency (OECD/NEA) was established in 1958 as a semi-autonomous body of the Organisation for Economic Co-operation and Development and currently includes 28 Member States from Europe, North America and the Pacific area. The programme of the OECD/NEA in the field of radiological protection in general and occupational exposure specifically is guided by the Committee on Radiation Protection and Public Health (CRPPH). One of the long-standing undertakings of the OECD/NEA in the field of occupational exposure is the Information System on Occupational Exposure (ISOE), initiated by the OECD/NEA and now supported by a Joint (OECD/NEA)–IAEA Secretariat. The ISOE has become a unique, worldwide programme on the protection of workers in nuclear power plants, and provides a forum for discussion of occupational exposure management issues, and is the world's largest database on occupational exposure due to nuclear power plants. The CRPPH is currently pursuing a dialogue with the International Commission on Radiological Protection on the system of radiation protection. The goal is to ensure that directions for improvement, agreed between radiation protection experts from national regulatory authorities, are taken into account during the development of new approaches and international recommendations. This process also includes involving radiation protection practitioners in nuclear installations — through the ISOE — in the investigation of the implications of any new recommendation on the protection of workers. The CRPPH also currently focuses on stakeholder involvement processes in radiation protection decision making, effluent releases of radioactive substances, radiological protection of the environment, and nuclear emergency preparedness and management.

1. INTRODUCTION

The programme of the OECD Nuclear Energy Agency (OECD/NEA) in the field of radiological protection in general and occupational exposure specifically is taken care of by the Committee on Radiation Protection and Public Health (CRPPH). The CRPPH organizes information exchange amongst senior policy makers, regulators, and senior representatives of research and development institutions from 28 OECD/NEA Member States, in order to harmonize views on important radiation protection issues. The cross-party representation, within the CRPPH programme of work of industry, safety authorities and governmental policy bodies makes the CRPPH a uniquely placed international forum.

The programme of the CRPPH currently focuses on the evolution of the system of radiological protection (in close co-operation with the International Commission on Radiological Protection (ICRP)), stakeholder involvement processes in radiation protection decision making, effluent releases of radioactive substances, radiological protection of the environment, nuclear emergency preparedness and management, and, importantly, the Information System on Occupational Exposure (ISOE).

This article gives a brief introduction to the occupational radiation protection activities undertaken within the OECD/NEA and the CRPPH.

2. THE OECD/NEA

The OECD/NEA was established in 1958 as a semi-autonomous body of the Organisation for Economic Co-operation and Development, and currently includes 28 Member States from Europe, North America and the Pacific area. In summer 2002, the Slovak Republic joined. The OECD/NEA is organized through a Steering Committee for Nuclear Energy under the OECD Council and performs its technical programme through seven standing technical committees and a data bank. The committee structure of the OECD/NEA is shown in Fig. 1. More detailed information on the OECD/NEA is available in its 2001 Annual Report [1] or on its website.[1]

3. OCCUPATIONAL RADIATION PROTECTION ACTIVITIES OF CRPPH

3.1. The ISOE

One of the long-standing undertakings of the OECD/NEA in the field of occupational exposure is the ISOE, which was initiated by the OECD/NEA in the 1990s and is now supported by a Joint (OECD/NEA)–IAEA Secretariat. Since its official start in 1992, the ISOE has become a unique, worldwide programme on the protection of workers in nuclear power plants, in addition to providing a forum for discussing occupational exposure management issues, and is the world's largest database on occupational exposure due to nuclear power plants.

The ISOE programme offers a variety of services in the field of occupational radiological protection, such as:

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[1] See http://www.nea.fr.

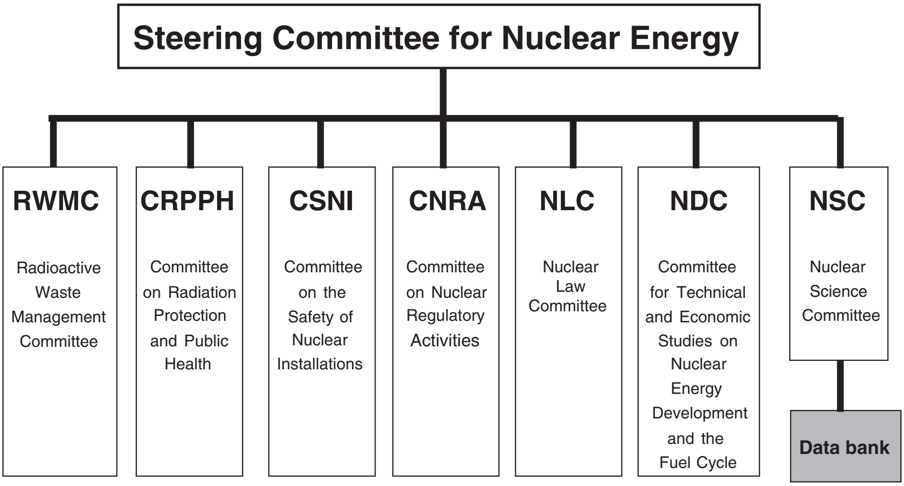

FIG. 1. Standing committees of the OECD/NEA.

(a) Access to the world's largest database on occupational radiation exposure due to nuclear power plants;
(b) A yearly analysis of dose trends and an overview of current developments, available through ISOE Annual Reports;
(c) Detailed studies and analyses, as well as information on current issues in operational radiation protection, available through ISOE Information Sheets;
(d) A system for rapid communication of radiation protection information, such as effective dose reduction approaches, effective decontamination procedures and implementation of work management principles;
(e) A forum for discussion of occupational radiation exposure management issues through ISOE workshops and symposiums.

Some of the above-mentioned components of the ISOE programme are reserved for the sole use of the participating utilities, which can thus utilize a closed network for information exchange on particular operational experiences. More detailed information on the ISOE programme can be found in Refs [2–4].

In addition to this long term programme on worker protection, the CRPPH offers a forum for senior radiation protection experts to discuss emerging issues in occupational radiation protection. These often lead to time limited and project oriented follow-up activities such as the survey on national practices in worker compensation, which was conducted in 2001.

The CRPPH programme also includes various other activities which are not directly related to occupational radiation protection but which will certainly have an impact on the protection of workers.

3.2. Evolution of the system of radiation protection

The CRPPH has pursued, for some time now, a dialogue with the ICRP on the system of radiation protection. With R. Clarke's proposal, in 1999, for a future system of radiological protection, the ICRP opened the discussion to the interested community and began the process of developing new recommendations. The CRPPH contributed actively to this development process by identifying, as a first step, where the current system of radiological protection (as per ICRP Publication 60) could usefully be improved [5]. In parallel, the CRPPH discussed policy level aspects of how stakeholder involvement can affect decision making in situations involving radiation exposure to the public or to workers [6]. Recently, concrete approaches to the evolution of the current system of radiological protection were proposed with the objective of making the system more transparent, simpler, coherent and easy to implement [7].

As part of the revision of the current system of radiological protection, a system for the radiological protection of the environment is currently being developed and will be integrated with the general system. The OECD/NEA has decided to organize, in collaboration with the ICRP, a series of three forums to promote and establish a process to assist the development of national policies and build an international consensus for radiological protection of the environment.

The CRPPH goal is to ensure that a consensus on directions for improvement is reached amongst radiation protection experts from national regulatory authorities, and that this consensus is taken into account during the development of new approaches and international recommendations. This will include — through the ISOE — discussion with radiation protection practitioners in nuclear installations investigating the implications of any new recommendation on the protection of workers.

One aspect of the ISOE programme, focusing on the operational aspects of radiological protection, involves ensuring that new recommendations from the ICRP will be operationally useful. Therefore, to assist the CRPPH in its work of contributing its viewpoints to the ICRP, it was agreed that the ISOE programmes' conclusions on key aspects of operational radiation protection could also form useful input to the ICRP. For this purpose, the ISOE steering group created the Working Group on Operational Radiation Protection to address these issues.

Within the context of the current ISOE programme of work, this working group will identify the key areas of importance in operational radiological protection at nuclear power plants, particularly as they relate to optimization processes. This work will take into account other work in this area, particularly the recent IAEA publication

[8]. The final report of the working group will be circulated widely, through OECD/NEA and IAEA channels, and will be offered to the CRPPH and to the ICRP for their consideration as input for new ICRP recommendations.

3.3. Effluent releases from nuclear installations

In support of the ongoing evolution of the system of radiological protection, a discussion on strategies with respect to radioactive effluent releases from nuclear installations in normal operation has been launched. Although radioactive effluent releases from nuclear installations have been reduced in recent years, they are still subject to discussions. The demand for further reductions is generally driven by societal concerns about the protection of the environment. The CRPPH Expert Group on the Implications of Effluent Release Options has started the work of identifying existing options for routine release of low level radioactive substances from nuclear installations with the objective of analysing their implications. An important issue in this respect is the potential risk transfer from the general public to workers in nuclear installations.

3.4. Stakeholder involvement in radiological protection

Modern society is moving towards a broad involvement of stakeholders in situations where difficult decisions have to be taken. In the field of radiological protection, the CRPPH initiated a programme to better understand the experiences and processes of involving stakeholders in radiological protection decision making. The first and second OECD/NEA Villigen workshops, hosted by the Swiss Government in 1998 and 2001 respectively, were key steps in developing the current general recognition of the importance of stakeholder involvement in some difficult situations. The third Villigen workshop is in the process of being organized by the OECD/NEA and will take place in late 2003.

4. CONCLUSIONS AND OUTLOOK

The programme of work of the CRPPH offers, through its cross-party representation of safety authorities and governmental policy bodies, a uniquely placed international forum in which to discuss current issues in radiological protection. The CRPPH has a long tradition in the arena of occupational radiation protection, especially through the ISOE. The CRPPH, therefore, facilitates and encourages the active involvement of the occupational radiation protection community as important ‘stakeholders’ in radiation protection issues, as exemplified by the current discussion on the evolution of the system of radiological protection.

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UNSCEAR's CONTRIBUTION TO OCCUPATIONAL RADIATION PROTECTION

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Abstract

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) summarized universal data on occupational exposure in the UNSCEAR 2000 Report. The current estimate of the worldwide collective effective dose to workers from human-made sources for the early 1990s, 2700 man·Sv, is lower by a factor of about two than that made by UNSCEAR for the late 1970s. A significant part of the reduction comes in the nuclear power fuel cycle, in particular in uranium mining. However, reductions are seen in all the main categories: industrial uses, medical uses, defence activities and education. This trend is also reflected in the worldwide average annual effective dose, which has fallen from about 1.9 mSv to 0.6 mSv. It is not yet possible to deduce any trend in the estimates of dose from occupational exposure to enhanced natural sources of radiation, as the supporting data are somewhat limited. The UNSCEAR 1988 Report made a crude estimate of about 20 000 man·Sv from that source, which was subsequently revised downward to 8600 man·Sv in the UNSCEAR 1993 Report. The comparable figure for 1990–1994 is 5700 man·Sv; however, an important new element has been added for this period, namely, occupational exposure to elevated levels of radon and its progeny, bringing the overall estimate of collective dose to 11 700 man·Sv. UNSCEAR also makes estimates of the detrimental health effects attributable to radiation exposure, including occupational exposure. It studies the mechanisms that lead to carcinogenesis and hereditary effects and also the available epidemiological evidence. UNSCEAR's risk estimates are applied by the IAEA, in co-sponsorship with other relevant international organizations within the United Nations family, for establishing international occupational radiation protection standards. The current international standards presuppose that above the prevalent background dose, increment in dose results in a proportional increment in the probability of incurring deleterious effects of 0.005% per millisievert of dose. Given this low risk factor and the relatively high prevalence of cancer among the population, for the reported levels of occupational exposure it is practically infeasible to detect any effects through epidemiological studies simply because of statistical limitations.

1. BACKGROUND

The United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) is a high level body within the system of the United Nations (UN), reporting directly to the UN General Assembly (UNGA) — the top of the pyramid in the UN system. UNSCEAR's clear mandate is to provide estimates on the levels of exposure to ionizing radiation (or radiation, in short) from various radiation sources and on the effects of radiation exposure. UNSCEAR estimates are reported periodically to UNGA and represent the position of the UN on the topic — a position that all the organizations within the UN family, such as the IAEA, shall follow.

UNSCEAR's estimates are essential for radiation protection and they provide the scientific basis for the development of occupational radiation protection standards. The latest position of UNSCEAR is stated in the UNSCEAR 2000 Report. UNSCEAR 2000 comprises two volumes, one on the levels of exposure, entitled Sources, and the other on the effects attributable to radiation exposure, entitled Effects.

Volume I assesses all sources of human exposure, including sources giving rise to occupational radiation exposure. Volume II analyses the biological effects of diverse radiation exposure levels, including levels encountered in occupational exposure situations (the volume addresses mechanisms, including radiation damage to the dexoribonuclide acid (DNA), which consitutes the human genoma in the chromosomes of the cell nucleus, the subsequent mutation phenomena, mutagenesis, and repair mechanisms, and the estimation of the magnitude of adverse health effects attributable to radiation exposure as well as the epidemiological evidence substantiating the occurrence of such effects). The UNSCEAR 2000 Report also includes a separate annex on exposures and effects resulting from the Chernobyl accident.

2. LEVELS OF OCCUPATIONAL RADIATION EXPOSURE

UNSCEAR has carried out a global survey of occupational radiation exposure through the submission of questionnaires to UN Member States. It has collected information on: radiation sources within the nuclear fuel cycle, sources used in medical and industrial applications, natural sources, sources related to defence activities and miscellaneous sources (such as exposure of aircrew to cosmic rays.) As a result, UNSCEAR 2000 constitutes the most comprehensive global database on occupational radiation exposure, which allows retrieval of substantive information on worldwide average radiation exposure. However, the information is far from complete, as will be realized from the papers presented at this Conference.

2.1. Individual levels of exposure

UNSCEAR 2000 presents data analysed up to 1994. The trend in exposure levels shows a decrease in the average annual effective doses attributable to occupational exposures; this trend applies to all activities between 1975 and 1994, as shown in Fig. 1. As regards exposures due to educational activities, there are unfortunately no data before the 1990–1994 period. UNSCEAR is currently analysing data from 1994 up to the present-day but the trend has not changed in this latter period as the paper on the Information System on Occupational Exposure (ISOE) clearly shows.

2.2. Number of monitored workers

Equally important, UNSCEAR 2000 shows an increase in the numbers of workers monitored for all the activities. This is still far from the worldwide number of 11 million occupationally exposed workers that this Conference's President was referring to in his opening address, but the numbers have been growing for all activities — notably in medical activities — as can be seen from Fig. 2.

The above numbers allow the inference to be drawn that the medical practice is definitively coming into the radiation protection family. Current new initiatives

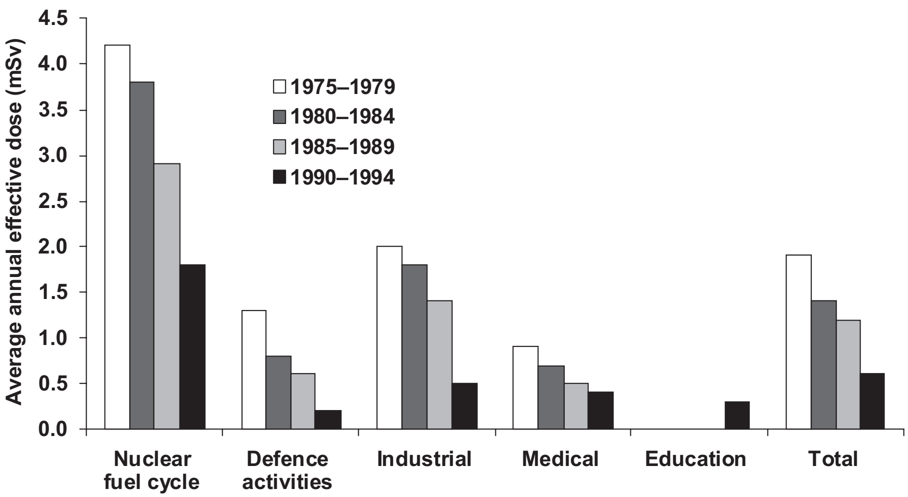

FIG. 1. Trends in worldwide average annual occupational dose.

on the radiological protection of patients are expected to bring the medical profession more into radiation protection and a clear increase in the number of monitored medical workers should be expected. It should be noted that an international action plan on the radiological protection of patients was approved by the IAEA Board Governors and endorsed by the IAEA General Conference. For the first time, the protection of patients will be on the radiation protection international agenda; previously the protection of patients was excluded from international radiation protection standards.

2.3. Occupational collective doses

The relevance of trends in occupational collective doses, i.e. the summation of all doses incurred by an occupationally exposed group of workers, should be assessed with extreme care. It may reflect changes in dose levels, but also changes in the number of monitored workers. If the collective dose is not associated either with a given activity (e.g. repairing a given piece of contaminated equipment), or generating a given amount of energy produced (owing to the operation of a given nuclear power plant), the analysis of the information can be tricky. However, in spite of the increase in monitored workers, the collective dose has also presented a decreasing trend over

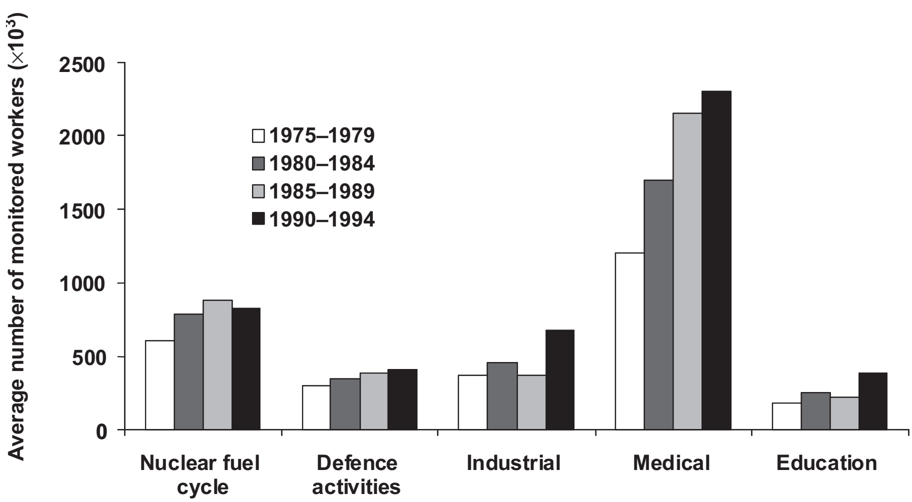

FIG. 2. Trends in worldwide annual number of monitored workers.

all these years basically all practices, as seen in Fig. 3, show; an overall trend towards better occupational protection.

2.4. Human made sources

The number of monitored workers was in the order of 4.6 million for the so-called human-made sources; Fig. 4 shows that the average dose calculated by UNSCEAR is 0.6 mSv/a, which illustrates improved occupational radiation protection when compared with the preceding 5-year assessment periods. For the nuclear fuel cycle the number is higher, 1.8 mSv/a, but still a very low average. UNSCEAR has not yet analysed — although this will change in the future — extreme cases where there may be problems of individual high doses.

2.5. Natural sources

Interestingly enough, around the world are a large number of workers exposed to enhanced natural sources, and UNSCEAR 2000 presents data on around 6.5 million workers. In coal mining, data on 3.9 million monitored workers are presented. The average doses attributable to these 'natural' practices are much higher than those attributable to human-made sources, with an average of around 1.7 mSv/a, but with

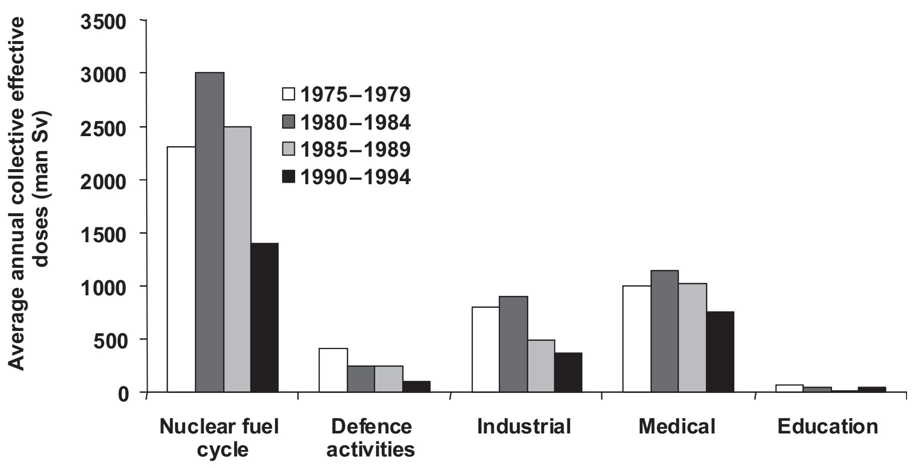

FIG. 3. Trends in worldwide average annual collective occupational doses.

Radiation source	Number of workers	Average dose (mSv/a)
Human made sources:		
• Nuclear fuel cycle	800 000	1.8
• Industrial uses of radiation	700 000	0.5
• Defence activities	420 000	0.2
• Medical uses of radiation	2 320 000	0.3
• Education/veterinary	360 000	0.2
Total	4 600 000	0.6

FIG. 4. Occupational exposures due to human-made sources.

certain workplaces where the dose averages 4.8 mSv/a and with extremes that can be considerably higher (see Fig. 5).

2.6. Summarizing the levels of occupational exposure

The overall picture on occupational exposures presented by UNSCEAR 2000 is summarized in Fig. 6, where the difference between human-made and natural sources can be seen clearly. The values range from a fraction of a millisievert per year for a number of activities up to values that can average almost 5 mSv/a for workplaces with high levels of background radiation.

Radiation source	Number of workers	Average dose (mSv/a)
Enhanced natural sources:		
• Mining (excluding coal)	760 000	2.7
• Coal mining	3 900 000	0.7
• Air travel (crew)	250 000	3.0
• Mineral processing	300 000	1.0
• Above ground workplaces (radon)	1 250 000	4.8
Total	6 500 000	1.8

FIG. 5. Occupational exposures due to natural sources.

Radiation source	Average dose to workers Number of monitored workers	 Effective dose (mSv/a)
Human made sources:		
• **Nuclear fuel cycle**	**800 000**	**1.8**
• **Other industry**	**700 000**	**0.5**
• **Defence activities**	**420 000**	**0.2**
• **Medicine**	**2 320 000**	**0.3**
• **Education/veterinary**	**360 000**	**0.1**
Total	**4 600 000**	**0.6**
Enhanced natural sources:		
• **Mining (excluding coal)**	**760 000**	**2.7**
• **Coal mining**	**3 910 000**	**0.7**
• **Aircrew**	**250 000**	**3.0**
• **Mineral processing**	**300 000**	**1.0**
• **Above ground workplaces**	**1 250 000**	**4.8**
Total	**6 500 000**	**1.8**

FIG. 6. Occupational exposures due to human-made and natural sources.

2.7. Comparison with other sources

It is interesting to compare UNSCEAR's occupational exposure estimates with average background exposures in general. UNSCEAR makes continuous evaluations of average natural exposure. At present, the average global value is estimated to be 2.4 mSv/a, with typical high values of around 10 mSv/a and extremes that can exceed 100 mSv/a. Human-made exposures of the public are negligible (except for medical exposures, which average 1.1 mSv/a in developed countries). In contrast, the average occupational levels are 0.6 mSv/a and 1.8 mSv/a for human-made and natural sources respectively (see Fig. 7).

2.8. Summary

UNSCEAR's summary of the overall picture of occupational radiation exposure can be expressed as follows: the overall trends for the average are clearly decreasing; the number of monitored workers is clearly increasing; and, in spite of an overall increase in the number of monitored workers, the worldwide average collective occupational dose is clearly decreasing (see Figs 8–10). This is a picture clearly illustrating a trend of improved occupational radiation protection over the years.

While UNSCEAR's estimates of the levels of occupational exposures present a picture of success, there is no room for radiation protection complacency. As

	(mSv)
Natural exposures:	
• World average	2.4
Human made exposures:	
• Atmospheric nuclear testing	0.005
• Nuclear power production (local)	0.01
• Chernobyl accident (First year: Eastern and Central Europe)	0.3–0.8
Medical radiation exposures:	
• Industrialized countries	1.1
• World average	0.3
Occupational radiation exposures:	
• Human made sources	0.6
• Natural sources	1.8

FIG. 7. Average annual exposures.

FIG. 8. Worldwide average annual effective dose.

FIG. 9. Worldwide average number of monitored workers.

FIG. 10. Worldwide average annual collective effective dose.

T. Taniguchi stated in his opening address, a view repeated in the ISOE presentation, it is possible to foresee future occupational radiation protection problems. These may be linked to the termination of practices, particularly those employed in the decommissioning of installations. Renewed occupational protection efforts will be needed if future UNSCEAR reports on occupational doses are to present as good a picture as the current one.

3. EFFECTS OF RADIATION EXPOSURE

UNSCEAR estimates the biological effects of radiation exposure, obviously including the exposure of workers. These estimates, after review by UNGA, become the UN position on the subject, which is then adopted and used by the organizations of the UN system.

3.1. Mechanisms of radiation effects

UNSCEAR considers that radiation exposure affects the centre of life, the DNA in the cell nucleus, and it is on the basis of this premise that the work of UNSCEAR has concentrated. Most of the UNSCEAR estimates deal with the effect of radiation on the cell nucleus and, in particular, on the genetic information in the DNA contained in the chromosomes, and on how radiation may alter that DNA information.

UNSCEAR has noted that radiation may alter the DNA through two mechanisms: direct action and indirect action. In direct action, the atoms constituting the DNA are ionized, thereby causing direct harm to the DNA. Indirect action creates radiolytic free radicals that then indirectly ionize the DNA constituents (see Fig. 11).

Ultimately, the effect will be basically the same and UNSCEAR considers that this interaction can result in simple damage to the DNA, producing basic mutations or some simple strand breaks which are relatively easy to repair, but which can also generate important clastogenic damage to the DNA, such as double strand breaks, which are very difficult for the repair mechanisms of the cell to handle. UNSCEAR has dedicated many studies to the repair of damage caused by radiation to the DNA (see Fig. 12).

In short, UNSCEAR considers that when radiation hits a nucleus either there is no change in the cell or a change occurs as a result of DNA mutation in that cell. If a DNA mutation occurs, either it is repaired (this happens often when there is a simple mutation as shown in Fig. 13 and the cell continues to be a viable cell for reproduction), or it is not repaired, which in many cases will result in the death of the cell, usually following a process of self-destruction termed ‘apoptosis’. Radiation induced cell killing will only cause a problem if a large number of cells die, otherwise there will be no problem. However, there is a small probability that the mutated cell

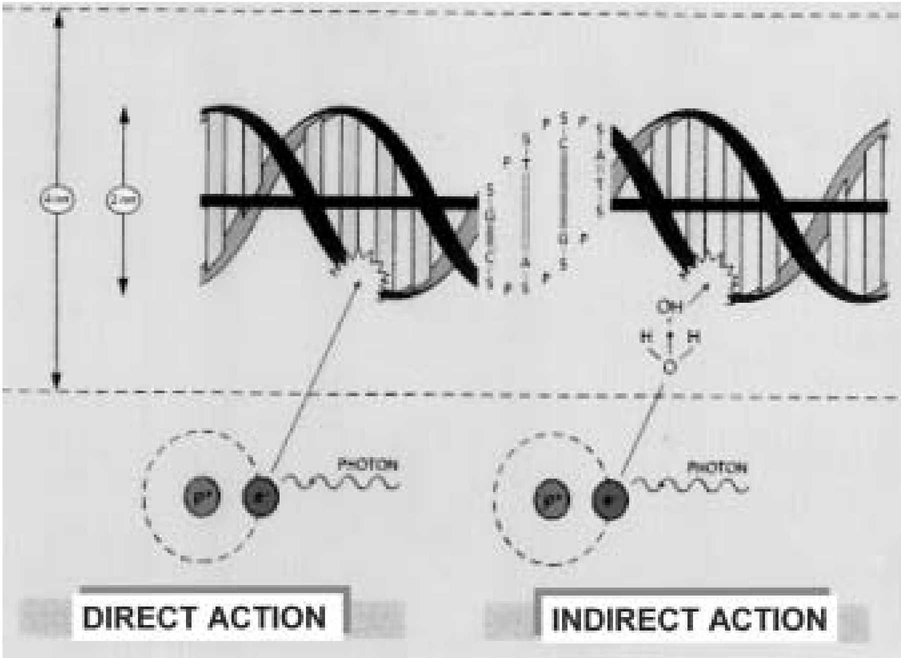

FIG. 11. Effects of direct action and indirect action on DNA.

will survive, and a mutated but viable cell can evolve into all types of damaging effect, one of which is cancer (see Fig. 13).

3.2. Epidemiological evidence of cancer

The epidemiological assessments of cancer risk studied by UNSCEAR are based on many sources but mainly on the epidemiological study of the survivors of the Hiroshima and Nagasaki atomic bombs, the so-called Life Span Study (LSS). The latest estimates of UNSCEAR from epidemiological studies are that the risk of fatal carcinogenesis after one sievert of exposure is 0.9% for leukaemia and 11.2% for solid tumours. The UNSCEAR 2000 estimates have not changed significantly over the previous UNSCEAR estimates of 1.1% and 9% respectively in the UNSCEAR 1994 Report, showing that the estimates are relatively robust. In summary, therefore, UNSCEAR presents a robust estimate at one sievert of around 1% per sievert for leukaemias (i.e. 0.00001 per millisievert) and of around 10% (or 0.0001 per millisievert) for solid tumours.

The excess radiation related cases among the atomic bomb survivors are very few and therefore very difficult to detect. In the exposed population 6800 cancer

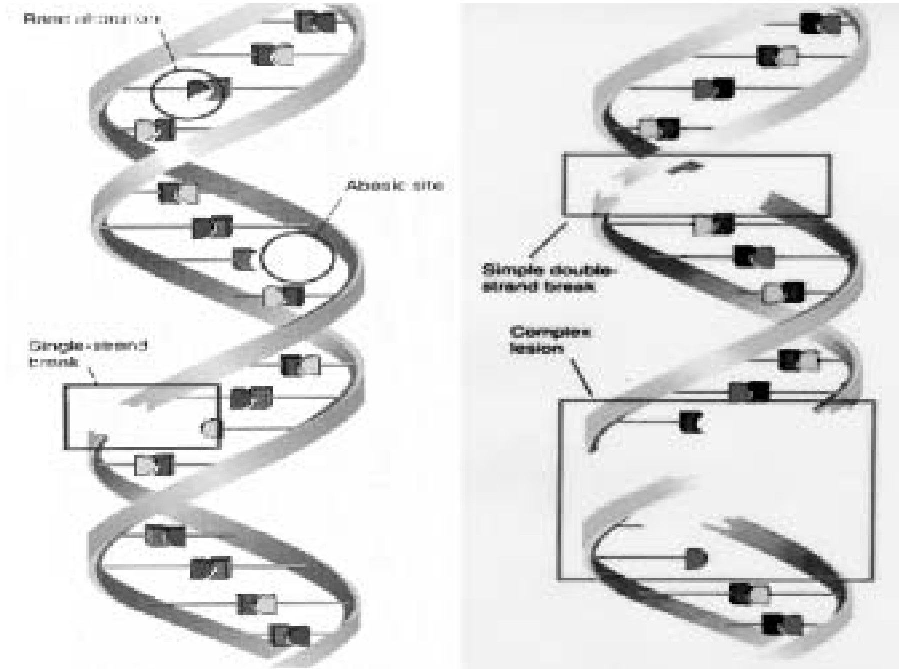

FIG. 12. Examples of damage to the DNA structure.

deaths would have been expected and UNSCEAR attributes around 300 more deaths to radiation exposure from the bombing. This means a 3.7 standard deviation from the expected value and it is by no means easy to detect, statistically, a standard deviation of 3.7 (see Fig. 14).

UNSCEAR has not only assessed epidemiological information from Hiroshima and Nagasaki, as is sometimes erroneously reported. There have been many epidemiological assessments undertaken by UNSCEAR, such as patients exposed to radiation for diagnostic purposes, nuclear energy worker studies, clusters of workers, and other clusters of individuals exposed to enhanced levels of environmental radiation. The results of these studies, in addition to supporting risk estimates from the Hiroshima–Nagasaki data, provide information on chronic and fractionated exposure and also on variability among populations — the Hiroshima and Nagasaki populations are very homogeneous — as well as on exposure to high level radiation.

3.3. Attributability of cancer to occupationsl exposure

The conclusions of the UNSCEAR assessment are that the dose response for solid tumours appears to be a simple fractional increase in probability with increasing

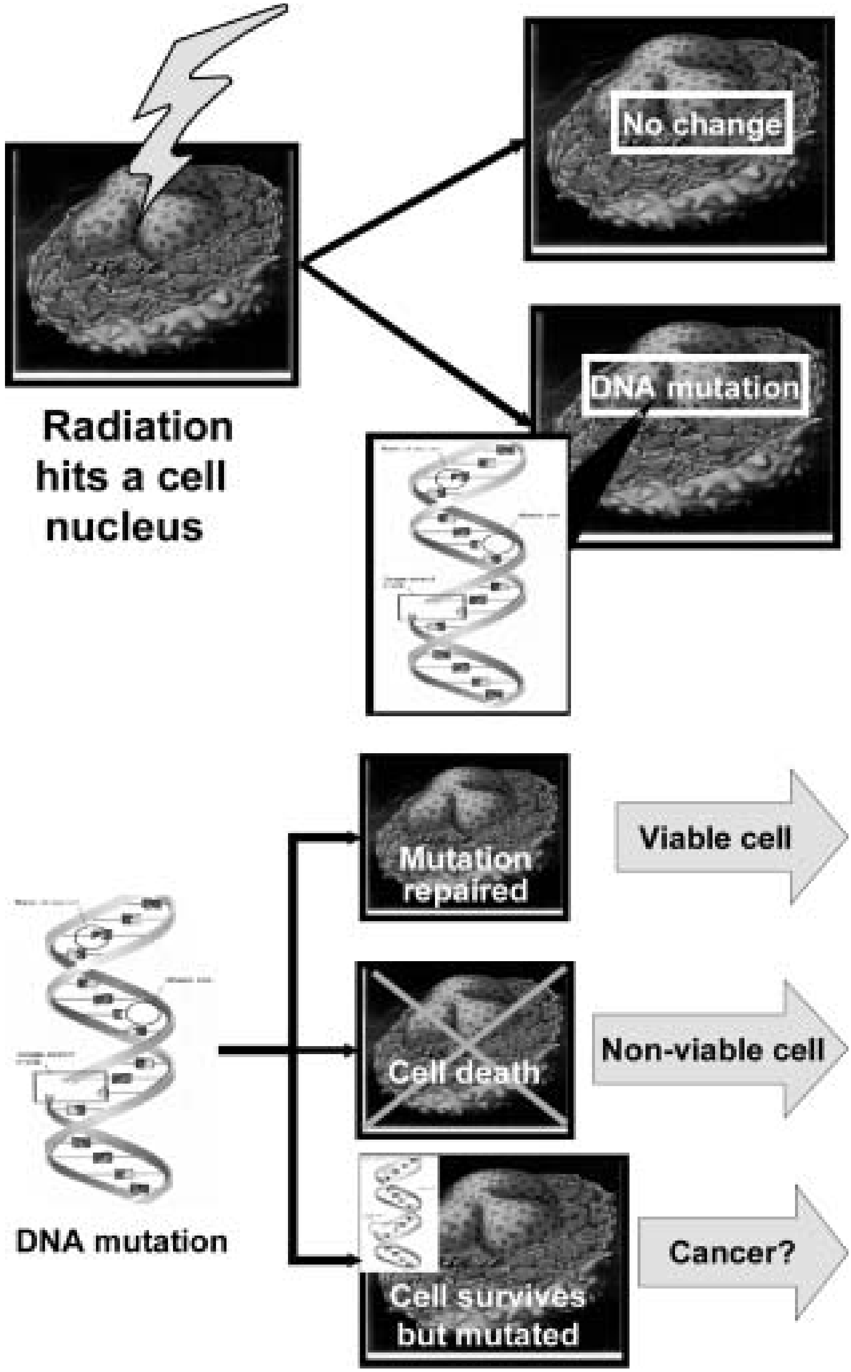

FIG. 13. DNA mutation due to radiation.

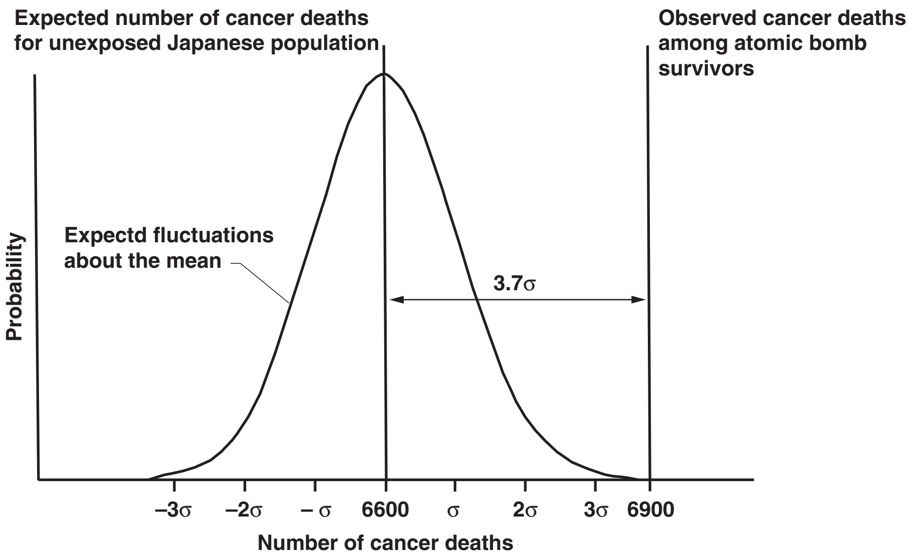

FIG. 14. Excess solid tumour deaths among atomic bomb survivors.

dose — the simplest being a linear one. In summary, UNSCEAR applies a reduction factor of two (the dose and dose rate efficteveness factor (DDREF) for extrapolating from the high dose and dose rate from the LSS cohort to the relatively low doses and dose rates expected in occupational exposure situations), the cancer risk estimates became 0.004–0.006% per millisievert, depending on the projection model used. In summary, around 0.005% per millisievert (a low risk but not zero risk) is the risk estimate used for occupational protection standards.

3.4. Hereditary effects

UNSCEAR produced a special report in 2001 on the hereditary effects of radiation. The report is very important because it quantifies very robustly the risk and shows that the risk of hereditary effects is very low, as suspected, owing to the fact that the hereditary effects of radiation have been impossible to ‘see’ statistically, even in the highly exposed LSS cohort. The risk value that UNSCEAR now takes for the hereditary effects of radiation is one tenth that of the risk of carcinogenesis (see Fig. 15).

Risks to offspring following prenatal exposure:

- **Total risk = 0.3–0.5% per Gy to the first generation (3000 to 4700 cases per Gy per one million progeny)**
- **Includes multifactorial diseases**
- **10% the risk of fatal carcinogenesis**
- **Constitutes 0.4–0.6% of baseline frequency**

FIG. 15. UNSEAR 2001 Report: Hereditary effects of radiation.

3.5. The debate on the linear no-threshold dose–response relationship

The latest UNSCEAR assessments have been released in the middle of a debate on the appropriateness of the linear non-threshold hypothesis of dose response, a debate which has resulted in several polarized positions: those who believe that radiation is good for you, those who believe that it is much worse than UNSCEAR has reported, and those who are in the middle and who are trying to rely on scientific data rather than emotions. The UNSCEAR position on this debate results from the evaluations that have been summarized here, and which can be expressed simply as follows: even at low doses, radiation may act as a mutagen and cancer initiator, and anti-tumorigenic defences are unlikely to be one hundred per cent effective. The simplest representation is the linear relationship, which is consistent not only with the available mechanistic information but also with all the quantitative epidemiological data that have been accumulated to date. There may be differences due to statistical variations (these are inevitable) and the actual response may involve multiple and competing processes. Although uncertainty remains, studies on DNA repair and the cellular and molecular processes of radiation tumorigenesis provide no good reason to assume that there will be a low dose threshold for induction of tumours. This represents UNSCEAR's position in general. Mechanistic models of radiation tumorigenesis areat a relatively early stage of development but the data available tend to argue against a dose threshold for most tumour types. Until the uncertainties on low dose response are resolved, UNSCEAR estimates that an increase in the risk of tumour induction proportionate to radiation dose is consistent with the developing knowledge and that this remains accordingly the most scientifically defensible approximation of low dose response.

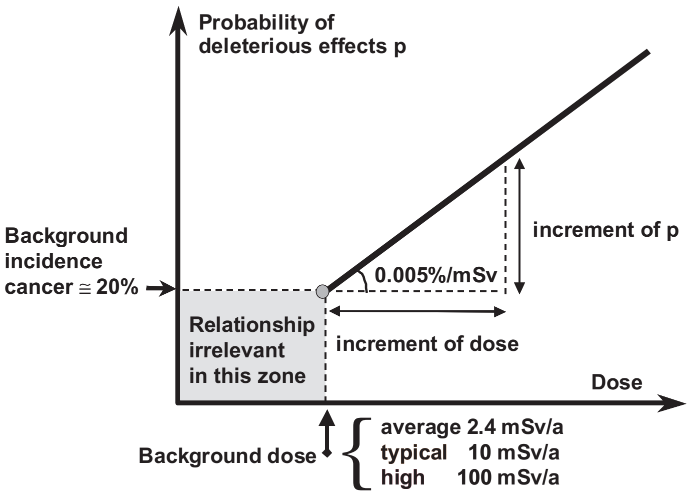

FIG. 16. Probability of deleterious effects.

3.6. Concluding: the dose–response for establishing occupational radiation protection standards

In summary, the UN position for establishing standards for occupational radiation protection is straightforward: above the prevalent background dose, an incremental dose would result in a proportionate increment in the probability of incurring deleterious effects; this value is in the order of 0.005% per millisievert. Graphically, as presented in Fig. 16, this means that above the background incidence of deleterious effects, which for some tumours is very high (about 25%), and above the background dose, which is also very high (varying from around one to hundreds of millisieverts per year), an increment in dose corresponds to a proportionate increment in probability, and the slope of the linear relationship is 0.005% per millisievert. The discussion in the area below the background levels of effects and dose is very interesting academically but has no relevance for establishing radiation protection standards.

3.7. Detectability of radiation effects attributable to occupational radiation exposure

Of course there is a serious problem with regard to detectability in radiation epidemiology (see Fig. 17). Because the additional risk attributable to radiation exposure is so low, this makes it difficult to detect induction of solid cancers at low

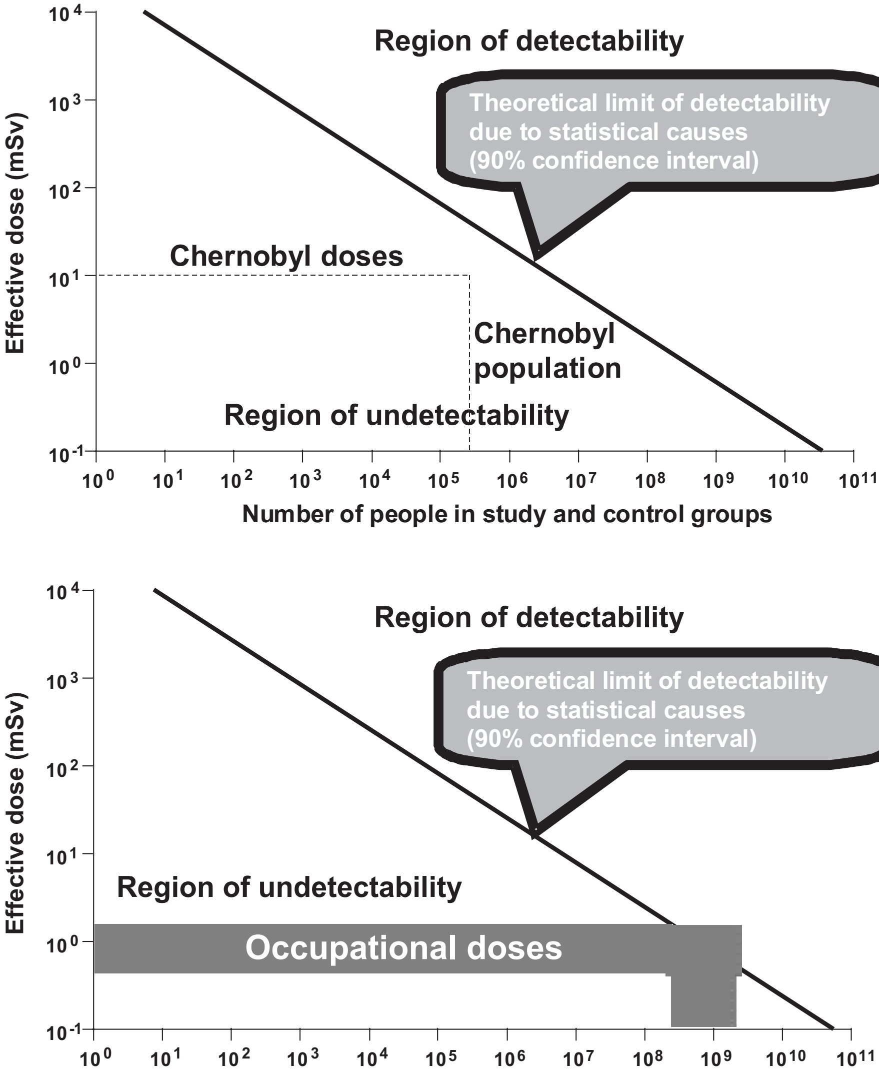

FIG. 17. Detectability limits in occupational radioepidemiology.

doses. Thyroid cancer is an exeption because it is so rare that small increases in the natural incidence could be detected. It is therefore not surprising that, for the cohort of people exposed to radiation from the Chernobyl accident, except for thyroid cases, no excess cancers have been detected — the doses are not great enough for detection. For workers, unless studies were to be performed on clusters of workers, the same problem of detectability would be evident. With the numbers for average dose in occupational exposures, a solid epidemiological study would need a population of 1000 million workers to obtain results of solid cancers. Any epidemiological studies of workers have to be well designed and concentrated on clusters of people who receive high doses.

4. EPILOGUE

As an epilogue, it should be stressed that ongoing and future studies in animal science and epidemiology will not solve the uncertainties in detecting human cancers attributable to radiation exposure. The statistical power will be insufficient. However, it should be remembered that *absence of evidence is not evidence of absence*. There is a continuing need for judgement based on data from cell and molecular studies. In this regard, UNSCEAR has an ambitious programme of work and expects to continue to provide estimates on levels in radiation exposure.

ICRP PRINCIPLES FOR THE RADIOLOGICAL PROTECTION OF WORKERS

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Abstract

The International Commission on Radiological Protection (ICRP) is a charity providing recommendations and advice on protection against the deleterious effects of ionizing radiation. The primary aim of its recommendations, as set out in ICRP Publication 60, is to provide an appropriate standard of protection for humankind without unduly limiting the beneficial practices that give rise to radiation exposures. The ICRP System of Protection (justification — optimization of protection — dose limits) is intended to prevent deterministic effects and to reduce the induction of stochastic effects as far as reasonably achievable. Specific advice concerning occupational exposures in practices and interventions is given in ICRP Publication 75. This discusses normal (routine) exposures and potential exposures, and also touches upon the safety of sources of radiation. It emphasizes the role of work management as the principal means of implementation of optimization, and addresses significant and frequently discussed issues such as exposure of pregnant workers, exposure of workers in emergency situations, exposures due to natural sources of radiation, monitoring of workers, health surveillance of workers and actions to be taken if exposures in excess of dose limits occur.

1. WHAT IS THE ICRP?

The International Commission on Radiological Protection (ICRP) is an independent registered charity, i.e. a non-governmental organization, established in 1928 by the International Society of Radiology. Its mission, according to its constitution, 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. These recommendations are published in the commission's journal, Annals of the ICRP.

There are 12 members and a chairperson in the main commission, some 70 members in the four standing committees (on radiation effects, on doses from radiation exposure, on protection in medicine, and on application of ICRP recommendations) and usually some 30–50 additional experts involved in various ad hoc task groups and working parties preparing draft reports. About a third of the commission is replaced at elections every four years. The legal seat of the ICRP is in the United Kingdom, while its small scientific secretariat is currently located in Sweden.

The activities of the ICRP are financed mainly by voluntary contributions from international and national bodies, such as licensing authorities, that have an interest in radiological protection. Some additional funds accrue from royalties on ICRP publications.

2. THE CURRENT SYSTEM OF RADIOLOGICAL PROTECTION

The current system of radiological protection as defined by the ICRP is given in ICRP Publication 60 [1]. The primary aim of the system is to provide an appropriate standard of protection for humans without unduly limiting the beneficial practices that cause radiation exposures. In order to achieve this, the system is intended to prevent deterministic effects of ionizing radiation, by keeping doses below relevant thresholds, and to minimize stochastic effects, by ensuring that all reasonable steps are taken to reduce exposures and thereby reduce the induction of stochastic effects.

The system comprises: (1) justification of practices that increase the level of radiation and of interventions aimed at reducing pre-existing levels of radiation, (2) optimization of protection such that doses from practices and risks from interventions, and the attendant probabilities of potential accidental exposure, are kept as low as reasonably achievable, and (3) dose limits for controllable exposures from human-made sources and from such natural sources that can reasonably be regarded as being the responsibility of the operating management.

There are also action levels for interventions against existing levels of radiation. Various factors influence the application of the system, such as the source of the exposure (practice or intervention), the situation when exposure takes place (public, occupational, medical), and the probability of incurring doses (near certain or potential).

On the basis of the linear, no-threshold dose–response approximation, no dose is regarded as completely safe. Therefore, dose limits cannot delineate dangerous from safe and are not efficient as tools to minimize radiation risks. Instead, optimization is the primary means of limiting risk.

The ethical basis of the system is primarily utilitarian, i.e. system actions are judged by their consequences, with limitation of collective doses for the benefit of society being an overriding consideration. However, dose limits and constraints are intended to avoid undue inequity in the distribution of individual risk, and therefore represent an element of deontological ethics invoking certain imperative duties.

3. FREQUENTLY ASKED QUESTIONS CONCERNING OCCUPATIONAL EXPOSURES

ICRP Publication 75 [2] provides guidance on good practice in the application of the ICRP System of Protection to occupational exposures. It deals in some detail with the management of occupational exposure in normal situations and in emergencies, monitoring of workers and the workplace for exposures, health surveillance of workers and the management of overexposed workers. A recurring theme is the optimization of protection of those at work whenever the exposure to radiation can reasonably be regarded as being the responsibility of the operating management. This relates to the choice between options in design and operation and to general work management principles.

3.1. What is an occupational exposure?

The conventional definition of occupational exposure to any hazardous agent includes all exposures at work, regardless of their source. This broad definition is unsuitable for radiological protection purposes, primarily because of the ubiquity of radiation of natural origin, some of which originates from sources that are uncontrollable. The ICRP therefore limits its application of the phrase ‘occupational exposure’ to “exposures incurred at work as the result of situations that can reasonably be regarded as being the responsibility of the operating management” [1].

Sources that are uncontrollable, such as ^{40}K in the body, should be excluded from the scope of regulatory control. Exposures received at work as a result of artificial sources in, or associated with, the workplace should be included in occupational exposures, with the exception of (1) medical exposures at work, (2) exposures from sources that have been formally excluded from regulatory control, and (3) exposures from sources exempted from the relevant aspects of regulatory control. Sources should be exempted if (a) they give rise to small individual and collective doses in both normal and accident situations, or (b) no reasonable control procedure can achieve a significant reduction in individual or collective doses [1, 3].

Doses to workers at one workplace, A, as a result of releases to the environment from another workplace, B, constitute a special situation. Since control at source is always preferable, such exposures should be controlled by restrictions at workplace B that should take exposures of the public and of workers at workplace A into account. Given sufficient control at workplace B, further control at workplace A is unnecessary.

Therefore, in summary, all exposures at work should be managed and controlled as occupational unless they have been excluded or the sources that give rise to them have been exempted. Regulatory agencies should exclude exposures from sources that are unamenable to control, primarily natural sources giving rise to general environmental levels of exposure. They should exempt sources giving rise to doses that are of no regulatory concern, and those that arise solely from operations that have been approved or authorized under other national arrangements.

It is important to note that ‘occupational exposure’ relates to the exposures from a source or practice, not to where a worker is working, whether inside or outside a designated area, and not to whether individual doses are assessed. Thus, all those who are working on a site where exposure is regarded as being the responsibility of the management are occupationally exposed, regardless of who employs them.

3.2. How should ‘normal’ and potential exposures be controlled?

The role of work management is the principal means whereby optimization of protection is implemented at the operational level. The overall approach to radiological protection is no different from that which applies to the management of work in general, including all aspects of health and safety. The primary responsibility for achieving and maintaining a satisfactory control of radiation exposures rests squarely with the management of the operation concerned. This has several aspects.

3.2.1 Policy and organization

To establish a safety based attitude in everyone concerned, there must be a substantial commitment to training and a recognition that safety is a personal responsibility and of major concern to the top management. Close links between management and workforce representatives are crucial.

3.2.2. Planning and implementation

For any place of work where occupational exposures to ionizing radiation are incurred, the operational control of radiation exposures should be structured and include (1) a prior radiological evaluation of all aspects of the operation, and (2) the establishment of an operational radiological protection programme, commensurate with the degree of hazard. The programme should include:

(a) Designation of controlled and supervised areas;
(b) Use of engineered controls to separate physically sources from workers;
(c) Use of clearly documented operational principles for normal work, protection activities and emergency actions;
(d) Provision of personal protective clothing and equipment;
(e) Provision of general information about radiation hazards as well as formal training;
(f) Provision of an established routine with which to measure, review and audit health and safety performance against pre-determined standards.

3.3. How should the exposure of pregnant women at work be managed?

In general, the ICRP sees no need to make any distinction between the sexes in the control of occupational exposures, but when a worker is known to be pregnant, the ICRP recommends a higher standard of protection for the conceptus. The early part of a pregnancy is covered by the normal protection of workers. Once the pregnancy has been declared, the working conditions of a pregnant worker should be such as to make it unlikely that the additional equivalent dose to the conceptus will exceed about 1 mSv during the remainder of the pregnancy [2]. In the interpretation of this recommendation, it is important not to create unnecessary discrimination against pregnant women.

The use of the ICRP System of Protection, particularly the use of source related dose constraints, will usually provide an adequate guarantee of compliance with this recommendation, without the need for specific restrictions on the employment of pregnant women. It is not necessary for pregnant women to avoid working with radiation completely or to be prevented from working in or entering designated areas. However, the exposure conditions of pregnant women should be reviewed carefully. In particular, their employment should not carry a significant probability of incurring high accidental doses and intakes.

Additional advice concerning pregnant medical staff (and pregnant patients) is provided in ICRP Publication 84 [4].

3.4. How are exposures in emergency situations treated?

Such exposures comprise several different situations covering a wide range of severity.

3.4.1. Occupational exposures directly attributable to an accident

Such exposures can be limited only by the design of the plant and its protective features and by the provision of emergency procedures. Ideally, the aim should be to keep doses within those permitted in normal conditions; while this is usually possible, it may not be feasible in serious accidents. Theoretically, any worker could be affected by an accident, although, of course, the probability can differ between different occupations.

3.4.2. Urgent emergency and remedial action at the site of the accident

This concerns ‘Category 1’ work [5] and is intended to save life, prevent the development of catastrophic conditions, etc. Both plant workers and emergency service workers such as firefighters can be affected. Dose limits are not relevant for these rare and unpredictable situations, but some dose limitation by operational control will still be possible. To avoid serious deterministic effects, effective doses that could exceed about 0.5 Sv should be avoided except for immediate life saving when dosimetric assessment may not be feasible.

3.4.3. Early protective actions and actions to protect the public

Such 'Category 2' work [5] implies additional exposures off-site and may include both plant workers and emergency service workers. Radiological protection should be optimized in a simple and straightforward way. The aim should be to keep doses below the occupational dose limits, but it must be accepted that strict adherence to dose limits may not be feasible for various practical reasons.

3.4.4. Recovery operations

Such 'Category 3' work [5] can be carefully planned and should be treated as a practice. The 'normal' system of protection should be applied and the occupational dose limits respected.

3.5. How should exposure to natural sources of radiation at work be handled?

Such exposures are 'occupational' if they should reasonably be regarded as being the responsibility of the operating management. The following situations have been identified.

3.5.1. Radon at work

Radon at work is dealt with in detail in ICRP Publication 65 [6]. Workplaces, including mines, in which intervention should be undertaken to reduce radon levels should be defined. Workplaces in which the ICRP System of Protection for practices should be applied to radon exposures should also be defined. A single action level, selected in the range 3–10 mSv/a, is recommended for both of these purposes.

At workplaces in which it has been decided to apply the ICRP System of Protection, periodic measurements may be needed to confirm that concentrations are not increasing in areas where the radon is not directly associated with the operations. If the radon concentration is largely due to the operations, controlled areas with special working procedures may be required. In such controlled areas, systematic monitoring of the exposure of workers will be necessary, and the local conditions will dictate whether this can be achieved by workplace monitoring or if individual monitoring is required.

3.5.2. Materials with elevated levels of natural radionuclides

Clearly, normal levels of natural radionuclides should be excluded from control. However, regulatory agencies need to determine whether the handling of large quantities of material with significant traces of natural radionuclides, or the processing of materials that may increase the concentration of such nuclides, leads to exposures that should be regarded as occupational and whether precautions are required to limit the exposure of workers.

3.5.3. Cosmic rays in jet aircraft

Exposures due to cosmic rays in jet aircraft should be regarded as occupational exposures. The annual effective doses should be determined from flying time and typical dose rates for the relevant routes. Existing restrictions on flying time are likely to provide sufficient control of exposures in most cases.

3.5.4. Space flight

The ICRP has not issued any guidance on radiological protection in the context of space flight, but an ICRP task group is currently preparing a report on this issue.

3.5.5. Other situations

In some special circumstances, other situations may also need to be addressed, including gamma radiation from natural sources in the ground or contamination from past practices (e.g. luminizing with paints containing ^{226}Ra).

3.6. Monitoring for radiation exposure: Why, when, what, who?

ICRP Publication 65 [2] includes a significant amount of detailed advice on this topic. The primary justification for monitoring is that it helps achieve and demonstrate an appropriate level of protection. In addition, there may be additional benefits in industrial/public relations, in scientific investigations, or in the determination of liability after adverse health effects in individual workers.

3.6.1. Types of monitoring

Routine monitoring of continuing operations confirms that working conditions remain satisfactory and that they meet regulatory requirements. Task related monitoring of specific operations provides data which allow immediate decisions to be taken on managing operations, and supports the optimization of protection. Special monitoring provides detailed information to supplement insufficient earlier information and enable problems to be elucidated and future procedures defined.

3.6.2. What is to be monitored?

Workplace monitoring can be performed for external radiation, air contamination and surface contamination. Individual monitoring can be performed for external exposure, internal exposure and skin contamination.

3.6.3. Individual monitoring for external exposure

Individual monitoring can demonstrate compliance with managerial and regulatory requirements, contribute to the control of operations and design of installations, and in the case of accidental exposures provide valuable information for further decision making. Such monitoring for external exposure is fairly simple and does not require a heavy commitment of resources. It should be used for all those who are occupationally exposed unless their doses are consistently low or, as in the case of air crew, it is clear that circumstances prevent doses from exceeding an identified value.

3.6.4. Individual monitoring for internal exposure

The purpose of individual monitoring for internal exposure is similar to that of monitoring for external exposure, but the practical implementation is more difficult and it is only recommended for workers in controlled areas with contamination and where there are grounds for expecting significant intakes. More detailed advice on monitoring programmes is given in ICRP Publication 78 [7].

3.7. What if there is an 'overexposure'?

Exposures in excess of the dose limit for occupational exposure comprise a wide range of situations.

3.7.1. Exposures suspected of being somewhat in excess of dose limits

Exposures suspected of being somewhat in excess of dose limits are unlikely to call for anything more than an investigation of the causes so that lessons can be learnt. If there is evidence of irresponsible actions, the worker may need re-training or transferring to other duties, but the dosimetric information should not in itself influence such decisions. If continued exposure is permitted, a formal dose limitation regime operative for the remainder of the control period should be established in consultation with the worker and the regulatory agency. Some degree of flexibility on the part of all of these is recommended.

3.7.2. Exposures substantially in excess of dose limits, but below the thresholds for deterministic effects

In addition to investigations as required, the supervising physician should be involved in order to provide advice and reassurance to the worker. However, unnecessary referral to the physician could increase a worker's levels of concern and stress.

3.7.3. Exposures around or above thresholds for deterministic effects

In cases where exposures are around or above thresholds for detemrinistic effects, the exposures should be estimated from clinical examination, observation and biological investigation. From this assessment, the likely clinical course should be anticipated and the appropriate medical and biological measures proposed. On this basis, appropriate treatment should be arranged. Early referral to specialist treatment installations should be considered. Owing to the rarity of such accidents, international co-operation has proved to be very valuable in such circumstances.

Exceeding a dose limit is not in itself a reason for excluding a worker from their usual occupation. However, the event may disclose pre-existing medical conditions for such exclusion. If the worker contributed to the event by irresponsible actions, then training or re-assignment to other work should be considered. Temporary suspension from normal duties can also be indicated if further exposures were to prejudice the interpretation of any desirable biological investigations.

Some of the particular problems in the case of overexposure of a pregnant woman are discussed in ICRP Publication 84 [4].

3.8. What about health surveillance in the presence of radiation?

A common responsibility of the operating management is to provide access to occupational services dealing with health. The principal role of this occupational health service is the same as in any occupation, i.e. to assess the health of the workers, to determine their fitness for tasks expected under the specific working conditions, and to provide a baseline of information useful in case of an accident or an occupational disease.

Three situations need to be considered in relation to occupational exposure to ionizing radiation. These are (1) when workers are required to use respiratory protective equipment, (2) when workers with skin damage or disease need to handle unsealed radioactive substances, and (3) when workers are known to have psychological disorders.

Previous treatment for malignant disease is not a reason to exclude an otherwise fit worker from working with radiation. Future occupational exposure is unlikely to increase the risk of cancer beyond what it would have been without the therapy. Likewise, in case of an enhanced genetic susceptibility to cancer in a worker, occupational exposure would still be a small contributor to the worker's cancer risk [8].

The supervising physician will need access to the relevant dose records, at least in case of an 'over exposure', and some of the data may need to be copied to an individual worker's medical record. However, it is of the utmost importance that confidentiality is not allowed to compromise the availability of the original data to the operating management and to non-medical professionals involved in protection.

4. REGULATORY ASPECTS

ICRP Publication 75 [2] does not explicitly endorse any particular regulatory philosophy, but the spirit of the report is very much that of a performance based regulatory system, where responsibility and accountability are given to, and demanded of, operations and individual workers, rather than being a prescriptive regulatory system which can tend to remove responsibility from the operator and place it on the regulator.

ICRP Publication 86 [9] discusses the prevention of accidents and stresses the importance of learning from experience. The report deals with patients undergoing radiation therapy, but the considerations about accident reporting and the dissemination of information are valid in other contexts too. It is particularly important not to devise a system where self-reporting is discouraged by unwarranted focusing on penal consequences.

5. PEEKING BEHIND THE CURTAIN: WHAT NEXT?

The 1990 Recommendations of the ICRP [1] were only implemented in national legislation relatively recently, even though the actual recommendations were drafted in the 1980s. Therefore, it is now time for the ICRP to begin drafting its next recommendations, which are expected to be approved some time around 2005 and may then be implemented in national legislation around 2010. The ICRP has taken particular care to involve the radiological protection profession in its discussion from the outset and to make its initial ideas available for discussion and modification, through the internet, for anyone with an interest in the topic. The process is likely to lead to some consolidation of the various items of guidance currently existing, and some technical details may come to be changed in the next ICRP recommendations. However, the philosophy and guidance detailed in ICRP Publication 75 [2] is expected to remain basically valid.

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THE ICRU: GENERAL OBJECTIVES AND ACHIEVEMENTS WITH REGARD TO OCCUPATIONAL RADIATION PROTECTION

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Abstract

The mandate of the International Commission on Radiation Units and Measurements (ICRU) — originally specified by the International Congress of Radiology in 1925 — is to develop concepts, definitions and recommendations for the use of quantities and their units for ionizing radiation and its interaction with matter, in particular with respect to the biological effects induced by radiation. Applications of ionizing radiation in medicine continue to be an important aspect of the work of the ICRU. Since the 1950s, however, work on aspects related to radiation protection for occupational exposure has continuously increased. The paper provides an overview of recent ICRU work in this area, including co-operation with the International Commission on Radiological Protection. Emphasis is given to the quantities for ambient and individual monitoring of external irradiations. The important aspects of recommendations and guidance on radiation measurements are also dealt with.

1. INTRODUCTION

1.1. Mandate of the ICRU

Thirty years after Röntgen discovered X rays, the First International Congress of Radiology, convened in London, recognized the need for the international standardization of units and measurements and, in 1925, appointed the International X-Ray Unit Committee, which subsequently became the ICRU. The mandate was

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intended to respond to the demands coming from the medical applications of X rays, but it was also recognized there were needs for harmonization in the area of radiation protection.

In 1928, the Second International Congress of Radiology reached an international agreement on the definition of a unit of X ray dose, the röntgen. It was based on measurements made with air-filled ionization chambers. In 1937, the ICRU recommended a definition of the röntgen applicable to both X rays and gamma rays.

As time elapsed, the applications of ionizing radiations in medicine expanded and the need for radiation protection of workers and the public increased. The extent of the activities of the ICRU expanded correspondingly. Currently, the fields of interest of the ICRU can be divided into the following main areas:

(a) Definition of radiation quantities and units,
(b) Measurement of radiation quantities,
(c) Provision of basic data for radiation interactions (radiation physics),
(d) Medical application of ionizing radiations for diagnosis and therapy,
(e) Provision of radiation protection of workers,
(f) Provision of radiation protection of the public (including radioecology).

At present, the ICRU is considering becoming involved in harmonization and standardization in the areas of industrial applications of ionizing radiations and in some specific applications of non-ionizing radiations.

1.2. Early steps in radiation measurement

The history of radiation measurement in general, and those taken for radiation protection purposes in particular, is a succession of different quantities and, in fact, units. Soon after Röntgen's discovery of X rays, many of the physical and even biological effects induced by X rays were used for radiation measurement purposes.

The radiation induced blackening of photographic film, which Röntgen observed was caused by X rays, was one of the early methods suggested for measuring and defining units of radiation. As it was, this technique did not play an important role in the history of standardization, but since around 1950 it has become an important method of individual monitoring.

Colour changes of chemicals, subsequent to X ray exposure, formed the basis of popular units for assessing irradiation for a considerable period of time (e.g. the 'pastille unit' (1904) for platino-barium cyanide capsules or the 'Holzknecht' or 'H' unit (1904) for mixtures of potassium chloride and sodium carbonate).

Also, various photoluminescent effects were detected early in the history of radiation measurement, including thermoluminescence, which Marie Curie reported as early as 1904, in her doctoral thesis.

The most important physical effect used for the initial phase of standardization, however, was ionization in gases. The first ionization chambers were built before the end of the century, and many proposals were put forward for units based on radiation induced ionization which led, finally, to the definition of the röntgen.

All proposed units were closely related to the measurement principle itself, and correlations to induced biological effects were established using ‘visible’ observations, mainly reactions of the skin. Not all of them were considered practical; for example, the proposal to use the depilatory effects of X rays did not find many supporters.

The reddening of skin was used to define a unit, the skin erythema dose, which was widely used as a reference and which was compared with the units based on physical measurements in an attempt to establish dose equivalencies.

These developments were almost totally restricted to medical applications. The focus on radiation protection of workers and the public only started in the 1950s with the development of nuclear industry and research applications.

1.3. Dosimetry in radiation protection

Development from the röntgen, the first internationally accepted unit of radiation measurement, to the currently practised system of quantities and units, embedded within a general concept of radiation protection, is the result of the work of the ICRU in collaboration with its sister organization, the International Commission on Radiological Protection (ICRP). This development was governed by:

(a) Scientific progress in the underlying disciplines of radiation physics and radiation biology,
(b) The rapid extension of the use of ionizing radiation and radioactive materials in medicine and in the nuclear and other industries since the 1950s,
(c) The recognition that radiation induced carcinogenesis and hereditary damage are the main risks associated with low dose exposures,
(d) The intention to generalize the applicability and improve the scientific rigour and consistency of the definitions.

The objective of radiation dosimetry, in general, is to provide procedures, techniques and concepts for the determination of the ‘amount’ of ionizing radiation that is quantitatively related to the induced biological effect. In radiation protection, dosimetry is thus concerned with the practical aspects of developing internationally accepted concepts, quantities and methods which are suitable for radiation risk assessment and which can be used for controlling exposures and for specifying exposure limits for radiation workers and the public.

2. QUANTITIES AND UNITS

One of the main objectives of the ICRU is to develop a universally applicable, coherent and consistent set of quantities and units for radiation measurement. This is essential for progress in all areas where radiations are encountered, i.e. from the nuclear energy industry through to research into medical applications.

The ICRU has developed and recommended a set of fundamental quantities and units which has been in wide use for many years and which has been vital to the successful exchange of information and comparison of results.

However, the field is not static and the expanding uses of radiation and radiation producing processes demand further development and elaboration of quantities which, in turn, imply development of new concepts and understanding that will facilitate meeting the new needs.

The ICRU, therefore, has a standing committee on Quantities and Units. The task of this committee is to maintain awareness of the new developments in the field and to clarify and improve the definitions of the existing concepts when appropriate, and to recommend new concepts and definitions when the need arises.

2.1. Development of concepts, quantities and units

Several milestones can be identified in the development of concepts, quantities and units for dosimetry in radiation protection:

(a) In 1953, at the 7th International Congress of Radiology in Copenhagen, the ICRU introduced the absorbed dose, D, in irradiated material, by any type of ionizing radiation, as the fundamental quantity correlated to the induced biological effect. The special unit introduced was the rad; now the special unit in the Système International is the gray.

(b) In 1962, the ICRU introduced — for radiation protection purposes — the quantity dose equivalent, H, as a product of absorbed dose and modifying factors, the most important of which is the quality factor, Q, to account for the differences in the relative biological effectiveness of different types of ionizing radiation. The special unit introduced was the rem; now the Système International special unit is the sievert.

(c) In 1977, the ICRP (Publication 26) introduced the effective dose equivalent, H_E, which is based on the dose equivalent in the various organs of an individual and the weighted sum of these, as a limiting quantity for all types of exposure. In 1991, the ICRP (Publication 60) modified its concept of protection quantities and introduced the organ equivalent dose, H_T, and the effective dose, E.

(d) In 1985, the ICRU (Report 39) introduced the operational quantities, ambient dose equivalent, $H^*(d)$, directional dose equivalent, $H'(d,\Omega)$, and personal dose equivalent, $H_p(d)$, for area and individual monitoring in the case of external radiation sources (Fig. 1).

Measurements of radiation protection quantities are often associated with significant uncertainties. In addition, large uncertainties and a variety of approximations must be accepted in relating physical measurements to the biological effects and risks caused by radiation. Although the requirements for accuracy in radiation protection measurements may not always be high, it is essential that the quantities employed be defined unambiguously, and that any approximations be clearly stated.

AREA MONITORING

Ambient dose equivalent, $H^*(d)$, at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded and aligned field, in the ICRU sphere at a depth, *d*, on the radius opposing the direction of the aligned field.

Directional dose equivalent, $H'(d, \Omega)$, at a point in a radiation field, is the dose equivalent that would be produced by the corresponding expanded field, in the ICRU sphere at a depth, *d*, on the radius in a specified direction Ω.

INDIVIDUAL MONITORING

Personal dose equivalent, $H_p(d)$, is the dose equivalent in soft tissue, at an appropriate depth, *d*, below a specified point on the body.

For weakly penetrating radiation:	d = 0.07 mm for skin d = 3 mm for eye
For strongly penetrating radiation	d = 10 mm

FIG. 1. ICRU operational quantities (source: ICRU Report 51).

2.2. Physical quantities, protection quantities and operational quantities

The ICRU's and ICRP's currently recommended system of operational and radiation protection quantities and units has been, or is likely to be, adopted by most national and international regulatory bodies. The system can be described as a hierarchy of quantities comprising physical quantities (including fluence, kerma and absorbed dose), protection quantities (organ absorbed dose, organ equivalent dose, effective dose) and operational quantities (ambient dose equivalent, directional dose equivalent and personal dose equivalent) (Fig. 2).

Physical quantities:

Fluence

Kerma

Absorbed dose

(quantities used in **METROLOGY**/standards laboratories)

Protection quantities (as defined by the ICRP):

Organ dose

Organ equivalent dose

Effective dose

(quantities related to the **RISK**)

Operational quantities (ICRU Report 51):

Ambient dose equivalent

Directional dose equivalent

Personal dose equivalent

(quantities related to radiation protection **PRACTICE**)

FIG. 2. Hierarchy of quantities in radiation protection.

ICRU Report 51, Quantities and Units in Radiation Protection Dosimetry (1993), summarizes all current definitions. It takes account of the formulations of protection quantities contained in ICRP Publication 60 (1991). A compilation of all quantities and units defined and recommended by the ICRU is given in ICRU Report 60 on Fundamental Quantities and Units for Ionizing Radiations (1998). Recently, the ICRU published a report on Quantities, Units and Terms in Radioecology (ICRU Report 65, published in July 2001).

Standards for the physical quantities are provided at standards laboratories, which also offer services for the calibration of instruments and dosimeters in terms of the operational quantities. ICRU Report 64, Dosimetry of High-Energy Photon Beams Based on Standards of Absorbed Dose to Water (May 2001), provides information on the current status of the methods used in primary standards laboratories.

The protection quantities, introduced by the ICRP, are conceived to be proportional to the radiation risk for almost all types of radiation. They were introduced mainly for the purpose of exposure control and thus risk limiting.

The operational quantities are defined either in the ICRU sphere (for area monitoring) or in the body (for individual monitoring). They are conceived to provide in the practical situations a conservative estimate of the relevant protection quantities. Therefore, individual and area monitoring with instruments calibrated in ICRU defined operational quantities permits the control of exposure with regard to dose limits.

The numerical relationships between physical quantities such as particle fluence and air kerma, and the protection and operational quantities have been determined using the calculational methods of numerical dosimetry, anthropomorphic phantoms for protection quantities, and the ICRU sphere for operational quantities. The hierarchy between the three sets of quantities is illustrated in Fig. 3, which was taken from ICRU Report 57/ICRP Publication 74, Conversion Coefficients for Use in Radiological Protection against External Radiation. This report is the product of a long collaboration between the ICRU and the ICRP. The report was prepared by a joint task group of the two Commissions and underwent separate review by each of the Commissions and has been published in the series of each Commission.

The report was published as ICRP Publication 74 in 1997 and as ICRU Report 57 in 1998. It provides an extensive and authoritative set of data linking field quantities, operational quantities and protection quantities to be used directly by those working in radiation protection for external exposure.

Conversion coefficients are provided for idealized irradiation geometries, mono-energetic radiations in anthropomorphic phantoms (mathematical models) and measurement phantoms.

As can be seen in Figs 4 and 5, the ICRU operational quantities almost always provide a conservative estimate of the ICRP protection quantities, which is of course particularly relevant to occupational radiation protection.

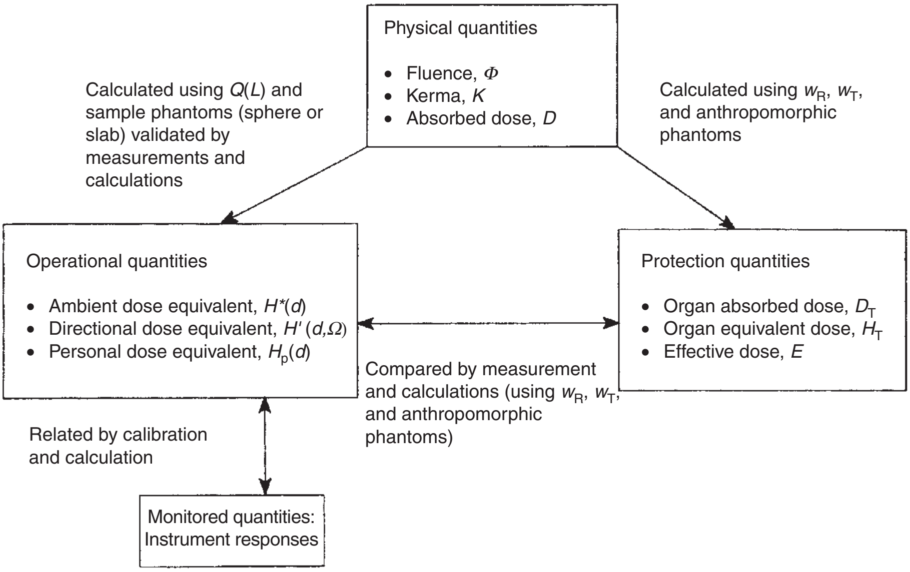

FIG. 3. Relationship of quantities for radiological protection monitoring purposes (source: ICRP Publication 74/ICRU Report 57).

Publication of ICRP Publication 74/ICRU Report 57 was very timely in view of the European Commission Directive revising the basic safety standards adopted by the European Council in May 1996 and the publication of the International Basic Safety Standards by the IAEA.

3. RECOMMENDATIONS FOR OCCUPATIONAL RADIATION PROTECTION MEASUREMENTS

The ICRU is involved not only in the development of concepts and quantities; it has also always played an important role in providing guidance on radiation protection measurements. An early example is ICRU Report 20, Radiation Protection Instrumentation and its Application (1970). ICRU Report 36, Microdosimetry, was published in 1983. Later on, the ICRU provided guidance for the determination of operational quantities in three reports. Report 43, Determination of Dose Equivalents from External Radiation Sources (Part 2), was published in 1988 and Report 47, Measurement of Dose Equivalents from External Photon and Electron Radiations, in 1992. More recently, ICRU Report 66 (October 2001), Determination of Operational Dose Equivalent Quantities for Neutrons, addresses occupational neutron radiation

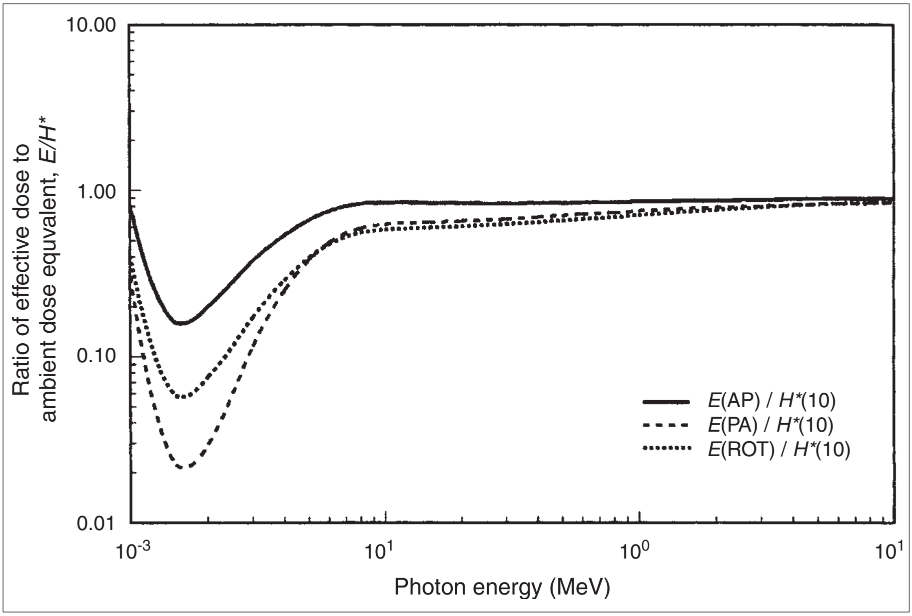

FIG. 4. Ratio of effective dose E to ambient dose equivalent H(10) for various irradiation geometries as a function of photon energy (3 geometries: AP, PA, rotational). The operational quantity (ambient dose equivalent) provides a reasonable evaluation (and for some energies even an overestimation) of the protection quantity (effective dose). It thus provides a conservative evaluation (source: ICRP Publication 74/ICRU Report 57).*

protection in the nuclear and civil aviation industries, and in medical and research applications.

In addition to issues concerning dosimetry for monitoring external irradiations, the ICRU addresses topics in the overall area of measurement of radiation and radioactivity for protection purposes.

Report 53, Gamma-Ray Spectrometry in the Environment (1995), was prepared in recognition of the fact that methods for the quick assessment of radionuclides in the environment have become increasingly important, particularly in connection with accidental releases from nuclear facilities.

Gamma ray spectrometry, based on measurement of the spectral distribution of the photon fluence, is used for the determination of activity levels in the ground or in air and of radionuclide specific dose quantities. It is also applied to the control of planned releases, in dose reconstruction and in environmental remediation projects, and in the search for radioactive sources in the environment.

Report 56, Dosimetry of External Beta Rays for Radiation Protection, published in 1997, recognizes that the general aim of beta ray dosimetry in radiation

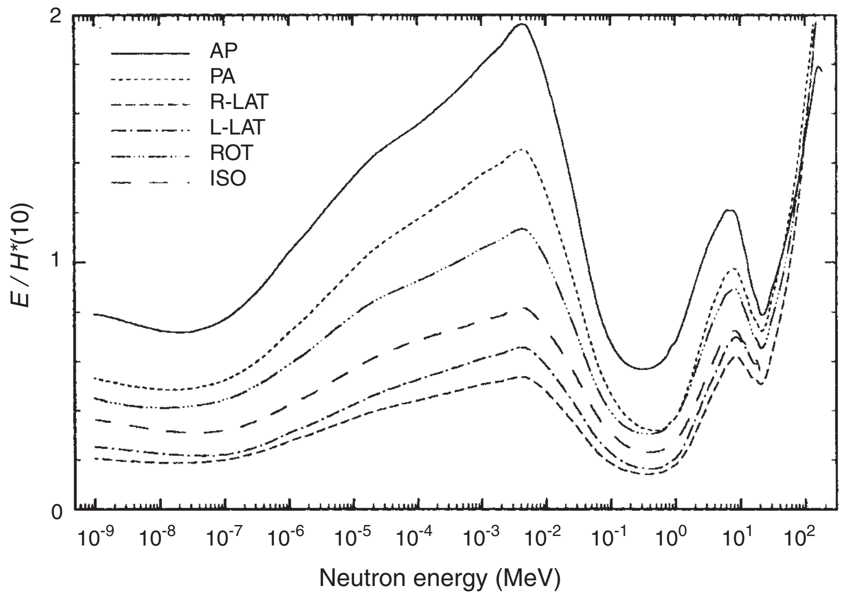

FIG. 5. Ratio of effective dose E to ambient dose equivalent H(10) for various irradiation geometries as a function of neutron energy (6 geometries: AP, PA, right-lateral, left-lateral, rotational, isotropic). The operational quantity (ambient dose equivalent) provides an overestimation of the protection quantity (effective dose) for most energies and most irradiation geometries. There is only an underestimation in a narrow neutron energy range and for some geometries (AP and ±PA). As the probability of having only this neutron energy (in these particular geometries) is small, it can be assumed that for practical situations the operational quantity is a conservative evaluation of the protection quantity (source: ICRP Publication 74/ICRU Report 57).*

protection is to provide dosimetric information that will help keep any harmful effects of beta rays within acceptable limits and that, in the event of serious overexposure, will assist medical treatment and prognosis.

The relevance of these reports to occupational radiation protection is obvious. With regard to occupational exposure, the ICRU has focused on external irradiation. However, in recent years, work on aspects related to incorporated radionuclides has been initiated.

The first example of this is Report 69, In vivo Determination of Body Content of Radionuclides (in press), which addresses mainly occupational protection issues. Also, ICRU Report 68, Retrospective Assessment of Exposures to Ionizing Radiation (in press), deals with the different methods of dose evaluation after radiation exposure due to external or internal sources.

Whereas in the dosimetry for external irradiation, the quantity absorbed dose proved to be useful for the majority of situations, limitations in the applicability of this quantity are found for exposures to some types of incorporated radionuclide, in particular nuclides emitting short range or low penetrating radiations. This is due to the requirements of the averaging process implied in the definition of the quantity. In general, it could be stated that the averaging process must be meaningful for the absorbed dose to be a useful prediction of the biological effect. Obvious examples of instances where the averaging process is not meaningful are the exposures resulting from incorporation of alpha and Auger emitters, but there are many others. This issue is discussed in ICRU Report 67, Dose Specification in Nuclear Medicine, which was published in August 2002. The conclusions drawn there are also relevant to occupational exposure.

4. CONCLUSIONS

The ICRU has played a decisive role in the development of concepts and quantities for radiation dosimetry in radiation protection for more than 70 years. The current system of quantities for radiation protection dosimetry meets the requirements of scientific rigour and practical applicability to monitoring over almost the entire range of exposure conditions of workers and the public.

Historically, in the field of quantities and units, one of the main contributions of the ICRU has been the introduction of the concept of absorbed dose to quantify ‘the amount of radiation’. The quantity absorbed dose (with its special unit, the gray) was found most useful for the majority of radiation applications and was universally accepted.

Efforts are still required to improve approaches to quantifying doses from heterogeneous distributions of radionuclides in tissues such as those encountered after incorporation of low activities of radionuclides in nuclear medicine or in occupational protection, and exposure of aircrew to cosmic radiation causing a few particle tracks (protons, ions) in the body.

Finally, the increased focus of the ICRU on providing guidance for specific measurement procedures and techniques will help harmonize the approaches and improve the reliability of results.

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ISOE: TEN YEARS OF EXPERIENCE

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Abstract

The Information System on Occupational Exposure (ISOE), sponsored by the OECD Nuclear Energy Agency and the IAEA, was created in 1992 to facilitate information exchange between radiation protection experts from both operating organizations and national regulatory authorities and to enhance international co-operation on worker protection at nuclear power plants. The ISOE programme offers the world's largest database on occupational radiation exposure due to nuclear power plants covering, in 2001, 93% of the commercial power reactors in the world. In addition to providing the basis for analyses of dose trends, benchmarking and detailed studies, the ISOE also offers a system for rapid communication of radiation protection information and a forum for discussing occupational radiation exposure management issues through ISOE workshops and symposiums, organized annually. This paper is based on a report, published in 2002, summarizing the experience gained from ten years' of developing the ISOE and containing comments from participants on their experience with the system. Growing use of improved work management procedures, developed and published through the ISOE, has contributed to the downward trend in the annual average collective dose per reactor. The impact of a steam generator replacement on the evolution of this dose has also been demonstrated. To maintain or even further reduce the already low levels of occupational exposure, the ISOE needs to be regularly used and further promoted by its participants. In future, the ISOE can also play an important role in the decommissioning and dismantling of nuclear power plants.

1. INTRODUCTION

During the 1980s, radiation protection experts in the nuclear industry, at utilities and at regulatory authorities were faced with new challenges in the management of worker protection at nuclear power plants. The main issue was the growing pressure to put into practice the conceptual approach of optimization of protection, which at that time was becoming one of the cornerstones of international radiation protection standards. This generated a feeling that worldwide progress in applying the optimization principle to the control and reduction of worker exposures could be achieved if the variety of managerial and operational approaches adopted in different nuclear power plants and in different countries were pooled, exchanged and compared in an organized way.

However, this would require a mechanism to exchange and review experience among health physicists. The idea was raised of creating an international database and a network of contacts and providing assistance, with the aim of establishing a bridge between regulators and operators in areas of common interest by involving regulatory authorities in discussions on the implementation of the 'as low as reasonably achievable' (ALARA) principle based on operational information. This idea proved to be successful, as is demonstrated by current participation in the Information System on Occupational Exposure (ISOE) by regulatory authorities from 25 countries.

The ISOE was created in 1992 to provide a forum for radiation protection experts from utilities and from national regulatory authorities to discuss, promote and co-ordinate international co-operative undertakings in the area of worker protection at nuclear power plants. The ISOE is promoted and sponsored by the OECD Nuclear Energy Agency (OECD/NEA) and by the IAEA, which provide a joint secretariat for the programme. The ISOE programme is managed by a steering group, the chairperson of which is selected from among representatives of the participating utilities.

The ISOE programme offers a variety of products in the field of occupational radiological protection, such as:

(a) The world's largest database on occupational radiation exposure due to nuclear power plants. As of December 2001, the ISOE database includes information on occupational radiation exposure levels and trends at 460 reactor units (406 in operation and 54 in various phases of decommissioning), operated by 73 utilities in 29 countries. This database thus covers some 93% of the total number (438) of power reactors in commercial operation throughout the world.

(b) A yearly analysis of dose trends and an overview of current developments are provided through ISOE Annual Reports [1], which summarize recent information on levels and trends of average annual collective dose at the reactors covered by the database, and provide special data analyses and dose studies, outage experience reports, summaries of ISOE workshops and symposiums, as well as information on principal events in ISOE participating countries.

(c) Detailed studies and analyses, as well as information on current issues in operational radiation protection, are provided through ISOE Information Sheets. Dosimetric and other data from nuclear power plants provide the basis for studies on dose related to certain jobs and tasks.

(d) A system is provided for rapid communication of radiation protection information, such as effective dose reduction approaches, effective decontamination procedures and implementation of work management principles. Whenever a utility wishes to share experience on good practices, radiological problems or other technical issues, the ISOE network may be used to request or send information through the e-mail system. This allows rapid response and interaction between interested participants.

(e) The ISOE programme provides a forum for discussing occupational radiation exposure management issues through ISOE workshops and symposiums. Each year, an international workshop or symposium on occupational radiation exposure management at nuclear power plants is organized, in turn, in Europe and North America. The objective of these workshops and symposiums is to provide a forum for radiation protection professionals from the nuclear industry, utilities and regulatory authorities to exchange information on practical experience gained on occupational radiation exposure issues in nuclear power plants.

A part of the above mentioned components of the programme is reserved for the sole use of the participating utilities, which can thus avail themselves of a closed network for information exchange on particular operational experiences. This paper is based on a report published in 2002 [2].

2. ACTIVITIES OF THE ISOE

2.1. Benchmarking analysis

The ISOE database forms an excellent basis for studies and comparisons of occupational radiation exposure data between nuclear power plants in various countries or even within the same country. To improve the significance and usefulness of these studies, comparative analyses of data from reactors having similar characteristics can be made. For this purpose, 'sister unit groups' have been defined within the ISOE database, each containing reactor units of comparable type and design. Except for gas cooled reactors, each reactor included in the ISOE database has been assigned to a sister unit group.

Using the ISOE software[1], participants are able to generate pre-defined benchmarking tables and graphs. They can create their own comparisons with other units, within the relevant sister unit group and/or in other sister unit groups. The bench-

[1] ISOE provides participants with software packages, including the ISOE database, the input module (ISOEDAT) and the interface programme containing predefined analyses (MADRAS).

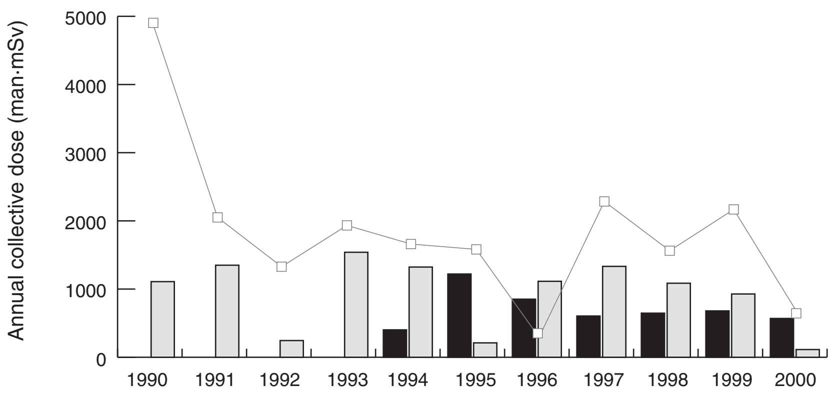
marking analysis is available at various levels, such as annual collective dose and dose per job (e.g. refuelling, steam generator primary side). An example is given in Fig. 1.

For a more detailed understanding of the results, participants can contact their responsible counterparts in other nuclear power plants directly by using the contact information available within the ISOE database.

2.2. Experience exchange

The communication network available to participants, using modern technology for real time information exchange, is one of the most useful features of the ISOE. ISOE participants can use their respective technical centre to obtain information and advice on specific radiological problems, radiation protection techniques, procedures of work and more. Each ISOE technical centre investigates questions raised by a participant, by contacting other ISOE participants directly or through the other ISOE technical centres.

For the above purpose, an e-mail system has been installed at the OECD/NEA Secretariat. This system also allows ISOE participants to exchange reports, questions and other information electronically with all other ISOE participants (utilities or authorities only, or both). In cases of general interest, a summary is published as an ISOE Information Sheet.



	1990	1991	1992	1993	1994	1995	1996	1997	1998	1999	2000
Daya Bay 1					402	1221	852	605	647	680	569
Koeberg 2	1109	1350	245	1540	1323	211	1114	1333	1086	928	113
Tricastin 1	4990	2020	1320	1919	1652	1584	281	2281	1554	2158	654

Year and corresponding dose

FIG. 1. Annual dose benchmarking for Tricastin 1 between 1990 and 2000.

ISOE expert groups can be established to conduct specific studies based on the needs of the participants. For example, an expert group was created to quantify the impact of work management on occupational radiation exposure. The report [3] generated by this group was widely distributed and translated into several languages.

As already noted, several types of document are made available to ISOE participants. These include the following:

(a) ISOE Annual Reports [1] presenting the evolution of occupational radiation exposure in nuclear power plants, as well as providing information on principal relevant events in the ISOE participating countries;
(b) ISOE Information Sheets (with ‘general distribution’ to all participants or ‘limited circulation’ to utilities only);
(c) Reports issued by expert groups.

Additional exchanges of experience take place during the annual steering group meetings. The ISOE Steering Group consists of representatives from utilities and regulatory bodies who, besides deliberating on ISOE management issues, review current developments and national trends in the operation and regulations of the nuclear industry from a radiation protection expert’s perspective.

2.3. Symposiums and workshops

Since 1997, the ISOE has developed a programme of annual workshops and symposiums for radiation protection professionals from all types of nuclear power plant. Attendees also include contractors and regulatory staff. The workshops and symposiums are held alternately in North America and in Europe. The European workshops are co-organized by the European technical centre and the European Commission, which provides a substantial financial contribution. The IAEA supports the workshops and symposiums by providing financial help for participants from countries participating in the ISOE through the IAEA and also for participants from the target countries of two IAEA technical co-operation projects aimed at enhancing occupational radiation protection in nuclear power plants.

The objectives of these meetings include the following:

(a) To provide a large forum for exchange of information and experience on occupational radiation exposure issues related to nuclear power,
(b) To allow vendors to present their recent experiences and current technology in the radiation protection area.

These workshops and symposiums have given hundreds of professionals the opportunity to listen to oral presentations (about 30 in each workshop), exchange information, share ideas and learn from others. The workshops' concept, with contributions from and for the radiation protection professionals, has proven to be very effective. It includes discussions in small groups on selected topics in Europe and practical ALARA training sessions in North America.

Further information exchange is accomplished by having the three best papers from each workshop presented at an alternate workshop. These papers and additional information are available on both the European technical centre website (http://isoe.cepn.asso.fr/) and the North American technical centre website (http://hps.ne.uiuc.edu). Non-participating individuals and institutions have access to these websites.

2.4. Expert group on work management

The ISOE Steering Group published an expert group report on Work Management in the Nuclear Power Industry in 1997. This was one of the first ISOE products that documented good radiological work management practices aimed at reducing occupational doses.

The preparation of the report [3] started in 1995 with the creation of an ISOE expert group of radiation protection managers from eight countries, including Canada, Finland, France, Germany, Sweden, Switzerland, the United Kingdom and the United States of America. The expert group was chaired by the USA. The contents of the report cover work planning, including scheduling and training, implementation and feedback.

Feedback from ISOE participating utilities on the report has been exceptionally positive. For example, reported applications of this document by US participating utilities include:

(a) Use of the report's outline and text as an ALARA assessment format,
(b) Use of the report's basic concepts to develop a site ALARA enhancement action plan.

The beneficial effects of the improved work management approach induced by the ISOE can also be seen in the continuous decrease in refuelling times. For example, average refuelling duration in the USA was reduced from 55 days in 1990 to 32 days in 2000.

The importance of providing applied information in the native languages of the nuclear power plant personnel of different participating countries was recognized by the ISOE Steering Group. This report was therefore translated into several languages, including Chinese, German, Russian and Spanish, in addition to its standard version in English.

3. ISOE DATABASE AND ANALYSES

3.1. ISOE reveals downward dose trends

The annual average dose per reactor began to show a downward trend during the early years of nuclear power. Since the beginning of the ISOE programme, this trend has been confirmed and consolidated, as can be seen in Fig. 2 showing data for the decade 1990–2000. Contributing to this trend are the improved communication and experience exchange between the radiation protection managers of nuclear power plants worldwide, provided by the ISOE network, as well as the growing use of improved work management procedures developed and published through the ISOE.

Although the data show some annual fluctuations, the average annual dose has been clearly decreasing for pressurized water reactors (PWRs), from more than 2 man·Sv in 1990 to less than 1 man·Sv in 2000. For boiling water reactors (BWRs), the dose came down from more than 3 man·Sv in 1990 to slightly over 1.5 man·Sv in 2000. The average annual dose for CANDUs in 1990 was already at a fairly low value of 1 man·Sv and has shown only some modest variations in the last decade. For gas cooled reactors (GCRs), the average annual collective dose, which was already lower than for other types of reactor, has continued to show a decreasing trend, from 0.5 man·Sv in 1990 to about 0.2 man·Sv in 1999.

The yearly fluctuations that can be seen in Fig. 2 for all types of reactor are due to variations in outage scheduling, changes in cycle length and the amount of maintenance work in the plants. For example, major work, such as the replacement of steam generators, leads to a significantly higher dose in the year of the replacement.

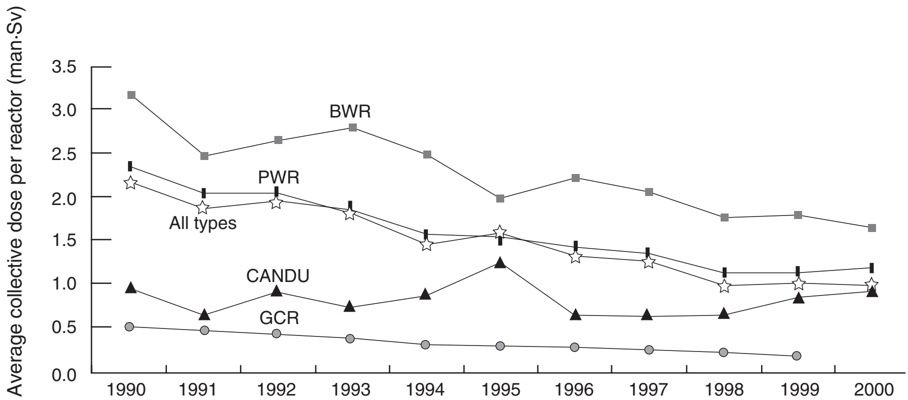


FIG. 2. Average collective dose per reactor for operating reactors included in the ISOE by reactor type for the years 1990–2000.

3.2. Steam generator replacements

Between 1979 and 2000, 58 steam generator replacements (SGRs) were performed, mainly in North America and Europe. Collective doses decreased regularly from more than 6 man·Sv per steam generator replaced in the late 1970s/early 1980s to an average of about 0.5 man·Sv during the last six years (see Fig. 3). However, that average masks quite large discrepancies and the best results correspond to three SGRs performed in 1996 and 1998 in Belgium and France with only 0.21 man·Sv per steam generator replaced.

A study was also made to evaluate the impact of an SGR on the evolution of the total annual collective dose for a reactor. The result is shown in Fig. 4.

3.3. Monetary value of collective dose

During 1997, a survey was performed within the ISOE network to better understand the usefulness of the monetary value of collective dose in the practical application of protection optimization. This value is commonly referred to as the ‘alpha value’. The results of the study are shown in Table I.

Eight regulatory authorities in charge of radiological protection (Canada, Czech Republic, Finland, Netherlands, Sweden, Switzerland, the UK and the USA) responded that they explicitly refer to the concept of monetary value of collective dose as a baseline reference for their regulatory decisions, and have defined one value or a set of values for this quantity. They also considered the implementation of the

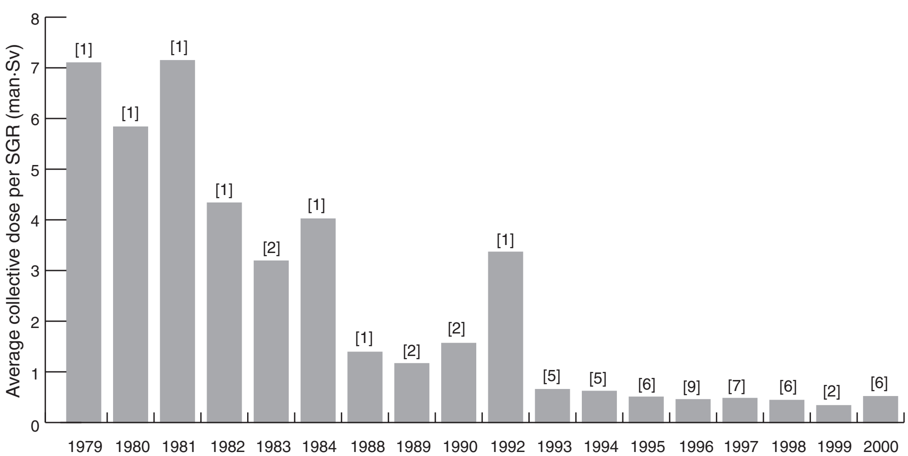


FIG. 3. Evolution of the average collective dose per steam generator replaced (number of SGRs considered is given in brackets).

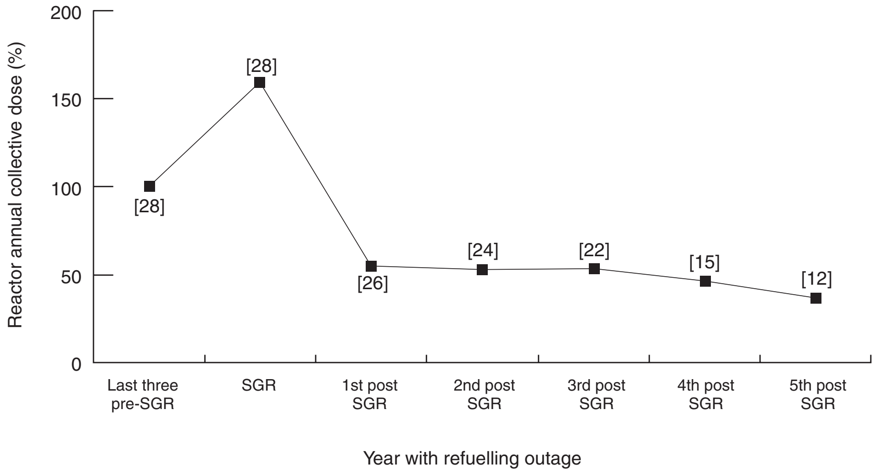


FIG. 4. Average impact of an SGR on the evolution of the reactor annual collective dose (number of data considered for the average calculation is given in brackets).

ALARA principle within the nuclear industry to be mainly an industry concern, and that, in this context, the monetary value of collective dose is essentially a managerial tool.

In most countries, alpha values are used when making decisions related to budget and impact on the operation and safety of a plant. About 60% of these applications are associated with significant modifications, large and expensive repairs, or chemistry of the plant.

As of 1997, nearly three quarters of the utilities represented in the ISOE had set up their own alpha value system. Some use a single alpha value, the average of which was about US$1300 per man·mSv for North American utilities in 2000 and US$600 per man·mSv for utilities in non-OECD countries, while some European utilities have established sets of monetary values which increase commensurately with increased risk.

TABLE I. ALPHA VALUES USED BY UTILITIES

Region	Alpha value US$/(man·mSv)			
	Type	Minimum	Average	Maximum
North America (2000)	Single value	500	1300	3300
Europe (1997)	Set of values	17	1000	5300
Non-OECD (1997)	Single value	4	600	1000

4. THE FUTURE OF THE ISOE

4.1. Improving the current system

During the last ten years, the ISOE programme has gained a high level of participation and support. The major challenges still facing the programme, in terms of improving its current performance and effectiveness, are the need to complete the ISOE database as well as to further promote information exchange on actual examples, best practices and lessons learned in the field of occupational radiation exposure management.

As the ISOE database is the backbone of the programme, it is essential for its success that the database be as comprehensive and updated as possible, containing detailed, up-to-date dose information for a variety of situations, jobs and tasks from all nuclear power plants worldwide. This completeness can be achieved only if and when all participants are motivated to input data that are as detailed as possible and to update their contributions regularly.

Information about experiences, lessons learned and best practices in occupational radiation exposure management over a wide spectrum of situations should be shared among all participants as soon as the analysis of an interesting task is reasonably finalized. In order to facilitate this exchange of information and experience, important technical means have been developed to input relevant reports into the current database and, at the same time, to distribute the information through electronic media to all ISOE participants. Efforts have been made to achieve a system which is easy to use and not time consuming. However, in the end, it is the commitment of participants to report on new experiences and to share them with other radiation protection experts that determines the usefulness and success of the system.

Another important challenge here is the need to make sure that the two-tier information exchange scheme established by the programme's terms and conditions can operate in a consistent and fair way. Careful management of the system is, in fact, necessary to ensure that the regulatory participants benefit from a fair share of information without, however, affecting the established right of the utility participants to preserve their own confidential channels for the direct exchange of detailed operational information.

4.2. Addressing new challenges

The ISOE is also beginning to face new challenges where adjustments and expansion of the system may be required. These will have to address the increased importance of the decommissioning and dismantling of nuclear power reactors, as well as the discussion on future nuclear power plant generations. Plant life extension of currently licensed facilities will also be part of future concerns within the ISOE. In all of these areas the ISOE can provide valuable information and a well-established community in which to discuss occupational exposure management issues.

As decommissioning and dismantling of nuclear power plants become more widespread, the ISOE can play an important role in managing occupational radiation exposure during these activities. Information exchange on this growing issue and the use of analytical tools developed within the ISOE will help achieve a higher level of protection for the workers involved in these activities. Information and experience contained within the ISOE system could also provide assistance in the design of new reactors, to ensure that an appropriate level of occupational dose management is built into their conception.

Another important concern for the future of the ISOE is the establishment of liaisons with international organizations, such as the World Association of Nuclear Operators (WANO), to further improve support of the ISOE by nuclear power plant managers. Occupational radiation exposure in other areas of the nuclear fuel cycle — research reactors, fuel production, waste treatment — could be considered for future inclusion in the ISOE.

5. CONCLUSIONS

The ISOE promotes efficient radiation work management and optimization of occupational radiation protection. It provides the tools, such as the database of the collective doses, reports, benchmarks, information exchange systems and workshops.

During its first ten years, the ISOE has gained a high level of participation, recognition and support. The active participation of a large number of utilities in this programme has contributed to a reduction in occupational exposure at nuclear power plants worldwide. In order to maintain or even further reduce the already low levels of occupational exposure, the ISOE needs to be regularly used and further promoted and supported by its participants, both the utilities and the regulatory authorities. Establishment of further interaction with international organizations, such as WANO, is needed with a view to further improving support of the ISOE by nuclear power plants.

In the future, the ISOE will continue to work in the field related to the operation of nuclear power plants, and it can also play an important role in achieving a high level of protection for the workers involved in the decommissioning and dismantling of nuclear power plants or in radioactive waste facilities.

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STAKEHOLDER INVOLVEMENT

(Briefing Session)

Chairperson

J. TAKALA
International Labour Office

VIEWS OF THE RADIATION PROTECTION PROFESSIONALS

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Abstract

The International Radiation Protection Association (IRPA) is an organization with a membership comprising individual professionals in radiological protection. Over recent years, the IRPA has played an increasingly important role in the standards setting process by collecting and transmitting views on proposals and by quickly informing the profession about developments within international bodies. The main concerns of the profession with respect to proposals from the International Commission on Radiological Protection are described, together with the areas of particular concern to the profession.

The concept of ‘stakeholder involvement’ is natural for a meeting hosted by the International Labour Organization, with its tripartite structure represented by the other speakers in this session. It is only fairly recently however that one of the stakeholders has been identified as being the radiation protection profession itself. Professionals may be employers, workers or regulators, but when speaking from the viewpoint of the profession it is the excellence of radiation protection itself that is the primary concern. The grouping of professionals is generally brought about through the professional society in their country and on an international level through the International Radiation Protection Association (IRPA). The IRPA is an organization with a membership comprising individual professionals in radiological protection who are also members of an affiliated national or regional society. The IRPA initially included 11 societies representing 16 countries. IRPA membership is now approaching 17 000 individuals from 43 societies covering more than 50 countries.

The primary objective of the IRPA as set out in its constitution is to provide a medium whereby international contacts and co-operation may be promoted among those engaged in radiation protection work, which includes relevant aspects of such branches of knowledge as science, medicine, engineering, technology and law. This effort to promote co-operation is meant to provide for the protection of humans and their environment from the hazards caused by ionizing and non-ionizing radiation and thereby to facilitate the exploitation of radiation and nuclear energy for the benefit of humankind.

Over recent years there has been an examination of the role that the IRPA can play in the establishment and review of radiation protection standards and recommendations. This activity, which is explicitly encouraged by the IRPA's constitution, has not received sufficient attention in the past, except in the non-ionizing radiation area. A clear consensus existed among societies present at the Associate Societies Forum at the last IRPA World Congress in Hiroshima in April 2000 that the IRPA must play a greater role in the standards setting process. Two processes have been set up to carry this out. One is for collecting and transmitting societies' views on proposals by standards setting bodies and another for quickly informing societies about developments within international bodies on which the IRPA acts as an observer.

The offer made by the International Commission on Radiological Protection (ICRP) to the IRPA to actively participate in the consultation process leading to the preparation of future recommendations was seen by all IRPA societies as an excellent opportunity to express the views of the professionals and they welcomed the direct interactions such as those that occurred during a special session in Hiroshima in the presence of Professor R. Clarke. The IRPA has continued this process with the compilation of comments from all societies that studied the initial ICRP proposals of 1999, which were transmitted to the ICRP secretary in July 2000. These comments were acknowledged as being influential by Professor Clarke in his progress report on the ICRP's new recommendations published in 2001 and this interaction will continue in the period leading up to the next IRPA World Congress in Madrid in May 2004.

The main concern of the profession has not just been to retain those aspects of the system of radiological protection that work and which are successful, but to 'fix' those areas where there are difficulties. It could, however, throw considerable doubt on the reliability of radiation protection principles if it were to be announced to the world that what we have been practising for the last several decades was somehow so wrong that it needs to be replaced. It is also very important that the 'goalposts' are not moved too frequently. The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources were only issued six years ago and are currently the focus of a major effort by the IAEA to introduce them into the legal and regulatory structures of some 100 countries around the globe. This effort is in addition to that being made to effect the European Directive. Both of these international instruments were the result of considerable debate on the wisdom of adopting the 1990 ICRP recommendations and on gaining the required governmental backing.

The ICRP and regulators set goals but it is the health physicist (or radiological protection professional) on the ground that is responsible for achieving them. The health physicist often has to interpret generalized goals in the real world context of power stations, industrial plant, hospitals, etc. Dose limits were fairly easy goals to understand and achieve but the 'as low as reasonably achievable' (ALARA) concept was another matter. The concept was appealing but the practical guidance from the ICRP when this was introduced in the 1970s was essentially limited to the use of cost–benefit analysis. This was later supplemented by clearer recognition of ALARA as a decision making process and tools such as cost-benefit analysis and multi-attribute utility analysis as decision aids. Professionals took the initiative in setting realistic and demonstrable industry and plant specific targets for the control of occupational exposures and in ensuring that they were achieved. The examples given at this Conference of decreases both in maximum individual dose and in collective dose, especially at nuclear power plants, are largely a result of those decisions and actions taken by the professionals at the working level.

Bearing this in mind, it is worth examining whether the proposed 'next recommendations' from the ICRP are really as fundamentally different as they are painted. To do this properly would require detailed analysis, which is not possible with the current outline proposals, but some indications can be gleaned. In doing this, I will concentrate on the application of optimization and action levels to occupational exposures, as it seems that the practical distinction between occupational, public and medical exposures will remain.

In occupational exposure control it seems likely that there will still have to be some 'dose limit' in the regulatory sense even if it is called an 'action level'. It seems unlikely that any employer or workers' representatives would permit occupational exposures above an action level defined as the level above which all reasonable actions should be taken to reduce doses. There is still to be 'optimization of protection' based on what may be called the 'workforce dose' rather than the 'collective dose to the workforce' which seems rather similar to current ALARA procedures. It also seems doubtful whether employers, workers and their representatives, or regulators would readily abandon a system which is relatively easy to monitor and enforce and with which all parties now seem able to work.

This demonstrates why the current involvement of the profession, through the IRPA, with the ICRP's next recommendations is so important. It is essential that the changes to be introduced are aimed at fixing the problems in the application of the system of protection and do not undermine the decades of achievement in both the interpretation of the generalized goals and their attainment. This is not to suggest that there are no areas where more could be done and the focus of the profession at this Conference should be to identify those areas where problems still exist, for example, the control of doses to medical practitioners in interventional procedures, to operators from accidents in industry and to those exposed to enhanced natural radiation, and to identify whether these need fundamental changes in the basic recommendations or better application of the current requirements. It is also important to identify areas where enough — or even more than enough — has been done; it must not be forgotten that ALARA has "reasonable" in it.

The overall message is that for future standards the emphasis should be on restricting changes to those needed to improve protection, and to make sure that any changes are workable in practice before they are introduced.

VIEWS OF THE WORKERS

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Abstract

This paper is written from the perspective of the worker. As such it presents the workers' viewpoint with respect to the present status and problems to be solved with regard to occupational exposure.

1. INTRODUCTION

I am very pleased to be able to represent the International Confederation of Free Trade Unions and I welcome this first international conference on worker protection. My brief is to represent the workers' viewpoint and I have been asked to give the workers' view on the present status and problems to be solved with regard to occupational exposure. That's quite a wide brief, and so I should like to focus on a non-exhaustive presentation, highlighting what I think are the major issues to address. My list of major issues is as follows:

(a) The importance of worker and union involvement;
(b) The problems caused by 'contractorization';
(c) The need to ensure that radiation health and safety (I will just refer to safety although, of course, health issues are the ones mostly being discussed) are management issues;
(d) The continuing need to focus on doses — both individual and collective;
(e) The coverage of nuclear safety programmes — by which I mean that the people who are exposed to radiation are often not what would traditionally be termed nuclear workers, and also that for the people who work in the nuclear industry, radiation is not always the main risk they face.

By way of introduction, however, I should like to acknowledge (admit?) two things. Firstly, I am not a nuclear worker, I am a national union representative. I have some understanding of nuclear safety issues and the nuclear industry, but my main specialism is in representing people. Secondly, what I have to state is coloured by the fact that I come from the unionized world — in the United Kingdom, the nuclear industry is highly, if not totally, unionized, and the relationship between management and unions is characterized by partnership, not conflict. Of course there are disagreements, but overall we are working towards the same goals, and one of the main goals is safety — and we have generally done very well in achieving that. I recognize that the same cannot be said everywhere in the world, but I think that that merely emphasizes the need for the solutions which unions can provide.

2. WORKER REPRESENTATION

The first item on my list flows from the involvement of trade union representatives in this Conference. We are very glad to be here, but it is fairly clear that we are in a minority.

Well, this is a conference of experts, and I am reminded that on at least one occasion the UK has been represented at events such as these by a government representative from our Nuclear Inspectorate and a worker representative who just happened to be the person who worked directly for this individual. Experts are also workers, and workers are experts, a theme I shall return to in due course. I merely wanted to acknowledge that just because there aren't too many trade union employees at this Conference doesn't mean that workers or union representatives are absent.

My concern is that workers' representatives are all too often confined to only a few of the issues in radiation protection. In reality, there is no area where unions cannot have a positive input and indeed ought to have a positive input. We don't just act as workers' representatives in the narrow sense.

In the nuclear industries, as I mentioned, workers are very often experts as well as being the people who provide the physical labour. They can contribute to the development of policy in all areas, from design to practices, to dose limits, to monitoring. We shouldn't just be part of the operation of the industry, commenting on decisions that have already been taken or fighting the corner of workers whose jobs are already defined, whose risks are already decided.

3. CONTRACTORIZATION

One area where trade unions really do need to be involved is in the management of contractors. In all industries, the same holds true. Contractors *can* be managed safely, but to do so often requires more effort than managing staff employed directly, and unfortunately that often means that contractors are *not* managed safely.

This is an issue that needs to be addressed as contracting becomes more common, and finds its way deeper and deeper into the heart of the industry. The days are long gone when all that contractors would do at a power station was to clean the windows! They are now often an integral part of the operation, and that causes problems that need to be overcome to maintain safety standards.

There is a specific union issue here. Even though it is sometimes badly handled, it is at least generally accepted that the interface between the employers and the contractors needs to be managed. No such assumption is necessarily made about the interface between the workforce of the employer and the contractor, and many of the faults of contracting flow from the bizarre management chain that one has to follow to get information passed from a group of workers to a group of contractors' workers. Unions have a great deal to offer here in managing worker to worker communication, and ensuring that consultation and provision of information operate across the contractor boundary.

4. LINE MANAGEMENT

Unions are fond of lecturing managers on how to do their jobs (and it's by no means one way!), but there is one area of management where we feel there really are problems. This Conference is, I am afraid to say, one of the symptoms of these problems.

Just as workers are absent from such events, then so too are managers. Not the people at the top of the organizations, but the line managers.

Unions are keen to see radiation safety dealt with as a little less of a specialism and a little more of a line management responsibility. There is always a vital role for specialists, of course, but one must beware of creating a ghetto out of specialisms, because you don't actually create or operate the risks — workers and line managers do.

One of the union representatives I spoke to before coming to this Conference said that the reduction in dose levels in my own country is at least in part a product of the greater knowledge and training of the workforce, and that is also true of line managers. Specialists can't do it all on their own.

5. DOSES

One of the other things I was told was that the picture on radiation doses is positive, but not yet positive enough. Dose levels are being reduced, and have been reduced substantially over the last two decades. Some people have suggested that this means we need to give less priority to dose levels in the industry (although they have never had the priority they should have outside of the industry, so the same argument does not apply uniformly). The view of the trade unions is that dose levels are still very important indeed, and not just individual dose levels.

It must be remembered that dose levels have two purposes: obviously to protect individual workers and ensure that they are not being exposed to too much radiation, but also act as early warning systems, identifying good and bad practice, and collective doses are therefore just as useful as individual doses.

6. SCOPE AND COVERAGE

Finally, I would like to mention two issues that go beyond the radiation exposure of workers in the nuclear industry, but which are very important to workers.

The first is that, as a chief medical officer at a nuclear facility put it, some workers are more at risk of being hit on the head by a spanner than of being exposed to radiation. We must not lose sight of the fact that in many of the better nuclear workplaces, the main risks are of repetitive strain injury, or slips and trips, or back strain or stress. Radiation is a natural focus of attention, but it is not the only issue, and the other hazards should be managed as well. In practice, there should be no problem with this. Good radiation risk management should be a facet of good risk management generally. However, all too often, humans compartmentalize, and deal with one risk at the expense of others.

The second issue, as the programme of this Conference acknowledges, concerns the large numbers of workers exposed to radiation, usually natural radiation, who are not in the nuclear industry at all — aircraft crew, for instance. Their needs for radiation risk management are just as important, but are all too often overlooked. In addition, there are, of course, large numbers of people whom we would consider to be at risk, but whose managers may not — industrial radiographers, health and research workers and so on. Again, this is about not putting radiation safety into a ghetto.

7. CONCLUSION

As I mentioned at the beginning, this is just a very brief summary of some of the main issues which unions are concerned about — discussion of the full version of our concerns would occupy the entire duration of the Conference. There are other trade unionists here and I would ask you to take what they say as seriously as we take what you say to us.

VIEWS OF THE EMPLOYERS

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Abstract

This paper gives the employers' viewpoint on aspects of occupational radiation protection.

1. INTRODUCTION

Occupational radiological protection is now a mature subject. This should hardly be surprising given that radioactive materials, and radiation, have been used in various forms for many decades, and their effects have been the subject of perhaps the most rigorous scientific examination and scrutiny afforded to any field. As a result, doses are generally low and may continue to fall, especially in those areas such as radiography, where special attention is increasingly being focused.

It might be argued that further major advances in the field are unlikely, although no doubt all stakeholders watch, or participate in, the debate on whether there is a threshold below which exposure to radiation has no adverse effect and, on the contrary, may even have a beneficial one.

So, one may legitimately ask whether, after all this time and scrutiny, there are any real problems to be solved, and why there is a need for a conference such as this. As noted elsewhere, the basic science can be considered to be mature (notwithstanding the threshold debate), and so it is not in this where the problems continue to lie, but in the philosophy and means of application. This is especially so in the current era where we are all trying to balance, on the one hand, increased efficiency, cost effectiveness and value for money with, on the other, a continuing pressure to raise standards to ever higher levels. Employers suggest that the means by which this dichotomy can be resolved is one, if not *the* major issue currently facing all stakeholders.

2. THE QUANDARY

In whatever field is being considered, society is becoming increasingly averse to risks of any level. For example, as a result of a small number of highly publicized incidents, some youth organizations in the United Kingdom are finding it increasingly difficult to undertake adventurous activities without having first satisfied Draconian authorization and permission regimes which are, in turn, rapidly making it impossible to provide young people with the kind of experience and development they seek and which is of considerable benefit in preparing them for successful careers.

As employers, we see a similar effect. Many of our stakeholders continually search for ways to achieve greater value for money, larger throughputs and more efficiencies, whilst at the same time demanding higher and higher standards — two competing requirements that, unless properly discussed and managed by all concerned, can lead to real difficulties. Not only is this a problem in itself, it is compounded by the lack of a consistent approach, either on a national or global basis.

For example, in the UK, organizations undertaking medical examinations using techniques that involve the use of radioactive materials come under pressure to undertake a greater number of such examinations, but with the same number of staff. This leads to a potential for increased exposures to the staff undertaking such procedures, even though their exposures are often higher than those employed in other fields. On the other hand, there is continuing pressure in nuclear and related industries to reduce exposures further, even though these are already well below internationally accepted dose limits, and in many cases 'trivial'.

Hence, one question that all parties must address is how to deal, in an appropriate manner, with a requirement for continual improvement when doses are already very low or trivial.

3. DIFFERING REQUIREMENTS

Although doses are very low, a fact that has already been mentioned, standards, expectations and approaches vary widely, particularly when considered in the global context. Although we live in a world and context that is increasingly international, where both workers and organizations are increasingly mobile, there is still widely varying regional, national and even local interpretation of international guidance and standards. This can and does create real difficulties where, for example, an organization from one country undertakes work in another country where standards are different. If standards in the country where the work is to be undertaken are lower than in the home country, should contracts be based on those of the home country (hence potentially making organizations uncompetitive in comparison with local employers) or should the home country's standards, and perhaps the values that the organization works to, be afforded a lower priority so as to attain work? These questions can lead to real difficulties, unwarranted costs and, eventually, business failures, not to mention the inability to attract key staff, because of perceived uncompetitiveness. It is not in anyone's interests for people to lose jobs and investment in areas, because of unnecessarily restrictive legislation, guidance or interpretation thereof.

4. THE WAY FORWARD

It is, therefore, suggested that review of the intent of regulation and guidance is needed, so that there is a clear understanding, agreement and means of application that is at least broadly shared by all stakeholders, but particularly by those who receive doses as part of their work (the employees) and by those who implement regulation and, as appropriate, guidance (the employers and operators). These stakeholders must be part of the development process, from the lowest to the highest levels.

It has already been noted that different areas can sometimes be subject to differing requirements and interpretations (e.g. the medical field, or the international differences mentioned previously). It cannot, however, be right that those who are exposed to radiation in one field or area are subject to a different level of regulation than those exposed in another field or area.

To avoid this sort of problem, it is suggested that the purpose of legislation should be to define the *minimum* safe parameters, or envelope, within which all practices operate, rather than what is 'nice to have'. Such legislation should be:

(a) Pragmatic — there is no point having legislation that cannot be implemented effectively or that is not properly understood.

(b) Equitable — all users must be fairly treated (for example, in this context there should be no differentiation between exposures from natural and artificial sources; the resulting doses to those exposed are the same).

(c) Global — otherwise, as discussed previously, individual groups, organizations or even countries could be disadvantaged or exploited.

This is not, however, to suggest that standards would necessarily be the same for each application. Individual users and organizations may well decide for themselves, in consultation with, and taking views from, a number of stakeholders, such as their employees, that higher standards are appropriate in specific areas. Beyond this envelope defining legislation, there is a need for agreed *practical* guidance on a range of issues that would really make a difference.

5. PRACTICAL GUIDANCE

The increasingly global nature of work with ionizing radiation means that common understandings of approaches to specific issues become more and more important. There are, undoubtedly, a large number of areas where agreed practical guidance would make a real difference and hence be welcome. Three examples or issues are covered below:

(1) The ‘as low as reasonably achievable’ concept is the cornerstone on which improvements are built, but there is a need for agreed practical guidance on exactly what this means in practice. For example, how are the differing inputs and desires mentioned previously reconciled — particularly trivial doses in a constantly improving world? A recent IAEA publication, Optimization of Radiation Protection in the Control of Occupational Exposure (Safety Reports Series No. 21), is an excellent step in this direction, but there must be agreement on what it means, how to implement it properly and avoid, in a systematic and proper manner, doing things for the sake of doing them.

(2) Great dividends would be realized if an easily understandable and applicable method of considering practical radiation protection techniques and approaches throughout the whole life-cycle of a process, but in particular during the design stages, could be developed. Such a process would need to involve all of those who may have valid input, but particularly the employees and other non-radiation protection professionals. An attempt must be made to reach a point where radiation protection becomes ‘demystified’ and simply a holistic and normal part of the working practices of all. Within the UK, and within my own organization in particular, it has been found that involving all relevant stakeholders in decisions ranging from policy formulation to determination of optimum working practices can bring huge benefits.

(3) Finally, in what is currently perceived to be a shrinking industry, it needs to be determined how best to attract, develop and retain competent staff. Perhaps greater use of secondments and other experience broadening measures would act as an aid to this.

6. SUMMARY

A point has been reached where there are, in the field of radiation protection, widely divergent standards both in legislation and in its application, at global, regional and national levels. An attempt must be made to get back to a point where regulations define the safe operating envelope and where individual organizations, in conjunction with their own particular set of stakeholders, then determine how far in excess of this they want or need to go, taking account of the specific drivers relevant to the particular case in point. This would enable resources to be directed at those areas where maximum benefit can be obtained (for example, the reduction of conventional injuries as opposed to the further reduction in operational doses, which are already very low).

Finally, there is a need for agreed, practical guidance on a number of issues that, as with the legislation discussed above, can be applied in a global context.

VIEWS OF THE REGULATORS

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Abstract

In dealing with a challenging problem in occupational exposure the nuclear regulator in South Africa concluded that the involvement of stakeholders was critical. Valuable lessons were learnt in the process. These related to co-operation amongst regulators, the involvement of regulators in addressing occupational exposure problems, the training of workers by the regulator and the need for technical training of the workers. In general, it was also learnt that regulators should establish mechanisms to measure and continuously improve the satisfaction of their stakeholders.

1. INTRODUCTION

The National Nuclear Regulator in South Africa started regulating mines in 1990. Assessments indicated that occupational doses in some mines were well above the dose limits. The involvement of all stakeholders was found to be critical to addressing the problem. This paper elaborates on some of the lessons that were learnt in the process of involving stakeholders.

2. THE STAKEHOLDERS

The first important step in the involvement of stakeholders in dealing with a problem is to identify the stakeholders that have an interest in the problem. With respect to the high doses in mines, the stakeholders were identified as being the employers, the workers and the regulator responsible for overall mine health and safety.

3. LESSONS LEARNT

There are several lessons to be learnt with regard to stakeholder involvement.

Lesson 1: Co-operation between regulators is critical

National legislation in South Africa provides for a shared responsibility in respect of radiation in mines. The responsibility is shared between the National

Nuclear Regulator and the mine health and safety regulator. Despite the recommendation of a commission on health and safety in the mining industry that the two regulators should co-operate, actual co-operation was minimal and interaction tended to be adversarial. This led to confusion on the part of the employers and the workers and provided the employers with the opportunity to renege on their responsibility. Later, the regulators recognized that co-operation was essential in the interest of achieving optimum occupational radiation protection. A common objective was formulated and both regulators participated in working groups aimed at addressing the problem. Their complementary expertise (i.e. in mining and in radiation protection) also contributed positively to the solution.

Lesson 2: In developing countries in particular, regulators have to become more closely involved in addressing problems related to occupational exposure

Generally, an 'arm's length' relationship between the regulator and the employer is preferred. In dealing with the high levels of exposure, the National Nuclear Regulator initially kept its distance and indicated to the employer that it should solve the problem. However, with the limited expertise existing in the country it was difficult to develop sustainable solutions. These difficulties were overcome when tripartite working groups (consisting of regulators, employers and workers) were established which involved some of the best independent technical experts in the country.

Lesson 3: In the initial development of an occupational exposure infrastructure the regulator must provide basic training to workers at authorized facilities

Initially, workers had little or no understanding of radiation hazards since these had not been regulated in the past. Employers did not have qualified experts to train workers and tended to focus on the costs of radiation protection and the possible job losses, which obviously became a major concern to the workers. Owing to their lack of knowledge in respect of radiation, workers would also tamper with workplace or individual radiation monitors. All of this delayed the implementation of effective occupational radiation protection programmes.

To overcome these difficulties, the regulator held various workshops aimed at providing workers with a basic knowledge of radiation hazards and radiation protection.

Lesson 4: Workers require extensive technical training to be able to contribute fully to structures in which they are involved

As mentioned before, tripartite working groups were established to address the problem of high doses in mines. Although the involvement of workers contributed to their understanding of the process, their practical contribution is constrained seriously by their lack of technical knowledge. This is a challenge that still remains to this day.

Lesson 5: Regulators should take care that co-operation is not used as a delaying tactic and should ensure that plans with clear deliverables are established

Once the above mentioned tripartite working groups were established, there was a tendency to regard the process as informal and to delay taking action from meeting to meeting. It was therefore found to be very important that the working group establish plans with clear deliverables, which may involve formal ubmissions to the regulator.

General lesson: Regulators should establish mechanisms to measure and continuously improve the satisfaction of their stakeholders

It is not the involvement of stakeholders in itself, but more their satisfaction with such involvement that would contribute positively to optimum occupational radiation protection. Regulators should therefore establish mechanisms to measure and continuously improve their stakeholder satisfaction.

RADIATION RISKS IN THE WORKPLACE IN PERSPECTIVE

(Topical Session 1)

Chairperson

ZIQIANG PAN
China

RADIATION RISKS IN THE WORKPLACE IN PERSPECTIVE

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Abstract

This paper puts occupational radiation risk into perspective with other risks encountered in the workplace and in society. The annual risk of fatal cancer associated with the average level of occupational exposure and the dose limit is compared with the annual risk of fatal occupational injury in other industrial sectors and with some annual risk of death from daily life. Finally, the lifetime risk associated with an exposure at the dose limit is set against the lifetime risk associated with exposure to dose limits of some chemical substances. The paper shows that the average level of radiation risk in the workplace is in the same order of magnitude as other risks for workers and follows the general trend in the reduction of risk at work observable in all sectors of the economy over the last three decades. The comparison also points out that at upper levels of individual doses, particularly when close to the dose limit, the level of risk deviates significantly from the main trends as far as risk estimates for other industrial activities are concerned. This calls for the need to pursue efforts in the implementation of the 'as low as reasonably achievable' principle in all domains.

1. INTRODUCTION

The objective of this paper is to put the occupational radiation risk into perspective with other risks encountered in the workplace and in society. The quantification of risk is not a straightforward exercise. It relies on a mix of science and value judgement in order to adopt the best possible evaluation, taking into account scientific data and uncertainties. It is always a reductive approach as it characterizes specific situations by a single number, putting aside all the elements which are characterizing the risk supported by individuals or groups. Keeping in mind the weaknesses and the limits of the approach, it is, nonetheless, a useful component with which to put situations involving risks into perspective.

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As far as radiological risk is concerned, the linear no threshold dose–effect relationship adopted by the international community is a convenient and broadly accepted tool to quantify the lifetime risk and the annual risk of health effects associated with any level of exposure. In order to obtain a clear picture of the radiological risk in the workplace, it would theoretically be necessary to consider the individual dose distributions associated with the various occupational exposure situations encountered in the different fields of activity. However, this introductory paper will, for the sake of simplification, focus only on two indicators: the average annual individual exposure level for all occupational situations as compiled by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the occupational dose limit. The latter is used to place the upper value of the tolerable risk adopted by the international community in perspective with other industrial and daily risks.

2. THE QUANTIFICATION OF THE RADIOLOGICAL RISK

The dose–effect relationship for radiation induced stochastic effects has been progressively established by an international consensus of scientists and expressed notably in the successive recommendations of the International Commission on Radiological Protection (ICRP), based on the knowledge accumulated in both radiobiology and epidemiology, and compiled and published periodically by UNSCEAR. Table I presents the lifetime risk coefficient per sievert for occupational exposure adopted by the ICRP in its Publication 60 [1].

In this paper, the risk of fatal cancer will be adopted as indicator to put occupational risk into perspective with other risks. The annual risk associated with the average annual level of occupational exposure in the medical and nuclear industry fields will be used (Table II). The annual risk associated with an exposure at the dose

TABLE I. NOMINAL PROBABILITY COEFFICIENTS FOR STOCHASTIC EFFECTS: ADULT WORKERS[a]

Stochastic effect	Detriment per sievert[b]
Fatal cancer[c]	4.0×10^{-2}
Non-fatal cancer	0.8×10^{-2}
Severe hereditary effects	0.8×10^{-2}
Total	5.6×10^{-2}

[a] Source: ICRP Publication 60.

[b] Rounded values.

[c] For fatal cancer, the detriment is equal to the probability coefficient.

TABLE II. RISK OF FATAL CANCER ASSOCIATED WITH 35 YEARS OF OCCUPATIONAL EXPOSURE TO IONIZING RADIATION

Exposure	Lifetime risk	Average annual risk
Average medical: 0.33 mSv/a*	4.6×10^{-4}	7.7×10^{-6}
Average nuclear industry: 1.75 mSv/a*	2.5×10^{-3}	4.1×10^{-5}
Dose limit: 20 mSv/a	2.8×10^{-2}	4.7×10^{-4}

* UNSCEAR 2000 Report data [2].

limit is also calculated, in order to present the upper bound of the radiological occupational risk. The calculations are made using the following method:

(a) Calculation of the lifetime risk associated with an occupational exposure incurred over 35 years at the average value encountered in the medical and nuclear fuel cycle fields, as well as with the annual dose limit. This lifetime risk is obtained by multiplying the level of annual exposure by 35 years and by the fatal cancer risk coefficient (4.0×10^{-2}/Sv). It should be noted that the ICRP in Publication 60 is using 47 years as the working lifetime for assessing the risk associated with the dose limit proposed for workers [1].

(b) In order to obtain the average annual risk, the lifetime risk is divided by the lifetime expectancy of individuals. In the case being considered, i.e. that of occupational exposure, it has been assumed that the exposure will start at 20 years old and that the lifetime expectancy at this age is in the order of 60 years. The lifetime risk has therefore been divided by 60 to obtain the average annual risk. Altogether, the various assumptions (value judgements) adopted above are reducing the risk coefficient by about 25% compared with the figures proposed by the ICRP.

The values of the average annual occupational exposure in the medical and nuclear industry fields are taken from the UNSCEAR 2000 Report [2]. These values have been selected in order to characterize globally the exposure situation to radiation, being aware that such a simplified approach does not give credit to the individual dose in the various domains in which workers are exposed. However, going into far more detail would not be very useful as it is difficult to find distribution of exposure as far as other risks to society are concerned. The risk associated with the annual dose limit is somewhat artificial inasmuch as that this value is rarely reached continuously over 35 years because of the implementation of the optimization principle which has been the driving force of the system of radiological protection over the last two decades.

Finally, one can notice that as the dose–effect relationship is linear with respect to the level of exposure, it is relatively easy to estimate the annual risk which would be associated with any values additional to those presented in Table II.

3. COMPARISON WITH THE RISKS ASSOCIATED WITH ECONOMIC ACTIVITY

A first way of putting the radiological risk into perspective with the other risks in the workplace is to consider the risk of injury in other industrial sectors and its evolution during the last 20 years. Three developed countries have been selected for the sake of comparison: France, Japan and the United States of America. The risk considered here is the annual rate of fatal injury. This rate is obtained by dividing the total number of fatal injuries in the considered sector of the economy by the number of workers employed in this sector.

Figure 1 presents the annual risk of fatal injury in France (1999) [3], Japan (2001) [4] and the USA (2000) [5, 6] on an average for all sectors of the economy (‘economic activity’), as well as for the specific sectors of manufacturing and construction. The manufacturing sector has been selected as it can be considered as representing activities relatively close to those involved in the nuclear industry and the construction sector is traditionally considered to be among the sectors that have the highest risk of fatal injury in all countries. The annual risk of fatal injury when all sectors of the economy are considered is in the order of 2×10^{-5} in Japan and 4×10^{-5} in both France and the USA; quite similar to the annual risk of fatal injury in the manufacturing sectors of these countries. The annual risk of fatal injury in the construction sector is in the order of 2×10^{-4} in the USA and 1×10^{-4} in both France and Japan.

Figure 1 also presents the level of the annual risk of death by radiation induced cancer associated with an average annual exposure of 1.75 mSv over 35 years and with an exposure at the dose limit of 20 mSv/a over 35 years. It appears that when considering the average value of occupational exposure, the annual risk of death is quite similar to that for the whole sphere of economic activity, with the manufacturing and construction sectors representing a risk 3–5 times higher, depending on the country. Figure 1 also shows that the annual risk associated with an exposure at the dose limit would be approximately ten times higher than the average annual risk of death in all sectors of economic activity. It clearly shows that the dose limit should be seen as an upper bound of the tolerable risk and that the implementation of the optimization principle leading to the reduction in exposures as low as reasonably achievable (ALARA) is the cornerstone of the radiation protection system.

It is also interesting to look at the evolution of the occupational risk of fatal injury with time. Figure 2 presents the annual risk of fatal occupational injury on average for all sectors of economic activity in France [3], Japan [4] and the USA [5, 6]

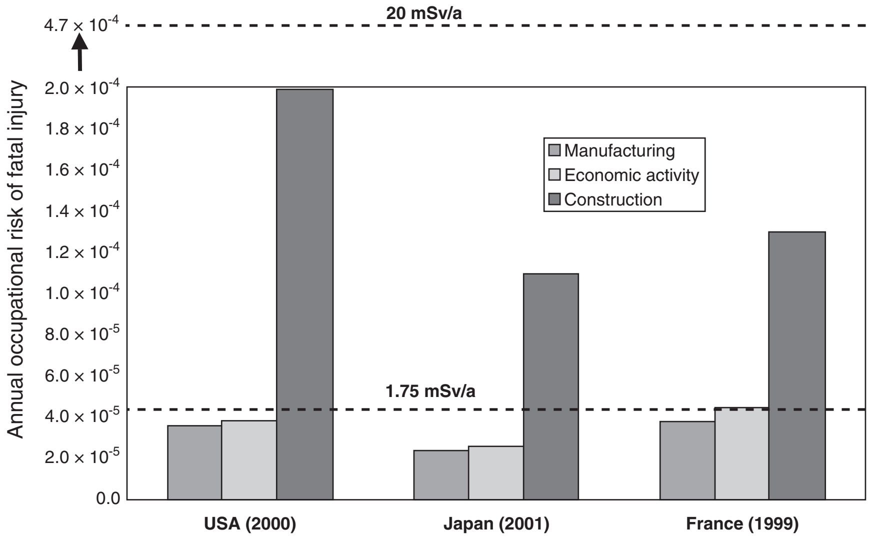

FIG. 1. Comparison of annual occupational risk of fatal injury.

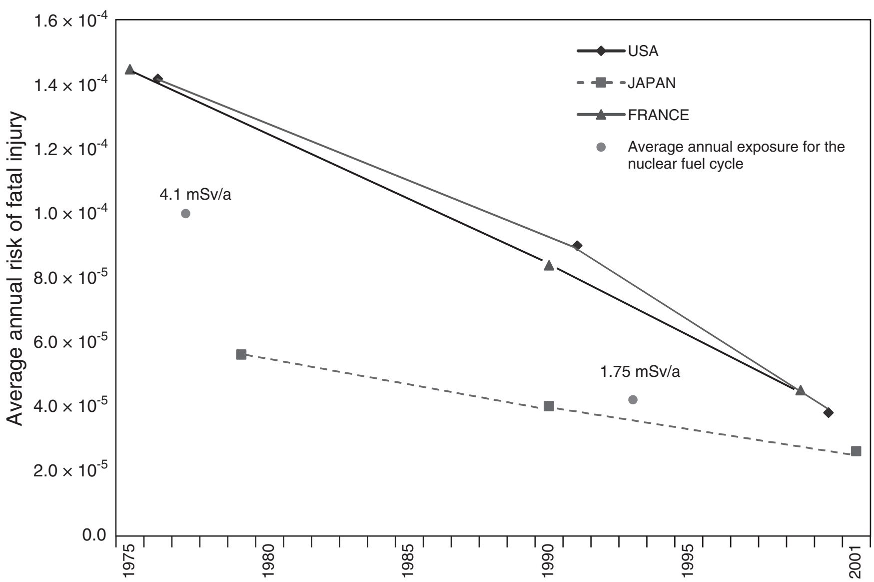

FIG. 2. Evolution of the average annual risk of fatal injury associated with economic activity and exposure to ionizing radiation.

from the mid-1970s up to the present. The decreasing trend of this indicator in all countries is also put into perspective with respect to the evolution of the annual risk of death associated with the average annual occupational exposure which decreased from 4.1 mSv in 1975 to 1.75 mSv in 1995 [2]. Finally, it is worth noting that the evolution of this average value is quite in line with the general trend in developed society towards a slow but regular improvement in the level of occupational safety in all branches of the economy. The average value for occupational exposure is maintained in the order of one tenth of the dose limit (i.e. 4.1 mSv when the recommended annual limit was 50 mSv until the late 1970s and 1.75 mSv in the early 1990s following ICRP Publication 60 recommendations). This remarkable evolution reflects the ongoing technical and organizational advances that have been achieved over the period through the promotion of good practice and the implementation of ALARA programmes in many organizations.

4. COMPARISON WITH OTHER RISKS

Another way of putting radiological risk into perspective is to compare the annual risk of death associated with the level of exposure with that of other risks from daily life. Table III presents the annual risk of death in the general population for all causes, as well as for the main causes of death in France [7], Japan [8] and the USA [8] using the year 1996 as the reference.

The individual average annual risk of death in all of these countries is quite similar, around 8×10^{-3}, the main cause of death being diseases of the circulatory

TABLE III. COMPARISON OF INDIVIDUAL AVERAGE ANNUAL RISK OF DEATH IN 1996

Type of risk	Country		
	France	USA	Japan
Death from all causes	9×10^{-3}	9×10^{-3}	8×10^{-3}
Circulatory system disease	3×10^{-3}	4×10^{-3}	2.5×10^{-3}
Cancers	2.5×10^{-3}	2.5×10^{-3}	2.1×10^{-3}
35 years exposure at 20 mSv/a	4.7×10^{-4}	4.7×10^{-4}	4.7×10^{-4}
Accidents at home	1.8×10^{-4}	1.3×10^{-4}	
Car accidents	1.5×10^{-4}	1.6×10^{-4}	1×10^{-4}
Radon at home	6.5×10^{-5}		
35 years exposure at 1.75 mSv/a	4.1×10^{-5}	4.1×10^{-5}	4.1×10^{-5}
Urban air pollution	2.6×10^{-5}		

system (2.5–4 10^{-3}) and cancers (2.5 × 10^{-3}). The annual risk of fatal cancer associated with an occupational exposure at 20 mSv/a during 35 years (4.7 × 10^{-4}) would be approximately 2.5 times higher than the annual individual risk of death due to car accidents in France or the USA and around 5 times lower than the annual individual risk of death by cancer (all causes).

The above comparison shows that for those workers exposed at the average level of exposure the annual risk is rather low and close to the background environmental risks due to radon at home or to urban air pollution. This type of comparison, although enlightening, must however be used with care. The risks put into perspective are very different in nature and it is difficult just to compare numbers when the risk situations are hardly comparable as far as the activities giving rise to these risks and the risk taking patterns are concerned. What is the commonality between breathing polluted air in a city, driving a car and smoking cigarettes? What are the benefits of such activities? In fact, these considerations demonstrate the limitations of this exercise and the experience with risk communication in the past has clearly demonstrated the weaknesses of using risk figures from very different activities to try to convince the workers or the general public about the ‘true’ risk of radiation.

5. COMPARISON WITH OTHER CARCINOGENIC SUBSTANCES

This section presents some comparisons between the risk associated with the occupational exposure to radiation and with other chemical carcinogenic substances. Table IV presents for nickel, arsenic, benzene and asbestos, the lifetime risk of occurrence of a cancer associated with exposure over a period of 70 years, 24 hours a day and during the whole year at a concentration of 1 $\mu g \cdot m^{-3}$ (or 1 $fibre \cdot cm^{-3}$ for asbestos). These risk coefficients have been adopted by the World Health Organization (WHO) in its recommendation regarding air quality in Europe [9]. In the same way as the ICRP acts for radiation risk, so the WHO compiles data from various biological and epidemiological studies in order to define the ‘best’ dose–effect relationship, taking into account present knowledge and uncertainties.

As in the radiation protection field, when a chemical substance has been recognized as carcinogenic for humans, the assumption of a linear no threshold relationship is always adopted as a prudent attitude to manage the risk, even if there is no scientific evidence of risk for the lowest levels of exposure (and because, in these cases, there is also no scientific evidence of the non-existence of risk). For comparison purposes, it is important to note that for the chemical substances presented here, the health risk is defined as the occurrence of a cancer, which is not in all cases a fatal cancer.

Because of the difficulty in gaining access to the average levels of exposure to chemical substances, the following comparison is restricted to the lifetime risk of cancer associated with an exposure over a period of 35 years at the limit of exposure

TABLE IV. DOSE–EFFECT RELATIONSHIPS FOR VARIOUS CARCINOGENIC SUBSTANCES

Substance	Effect	Risk coefficient[a]
Nickel (plus nickel compounds)	Lung cancer	4×10^{-4} $(\mu g \cdot m^{-3})^{-1}$
Arsenic	Lung cancer	1.5×10^{-3} $(\mu g \cdot m^{-3})^{-1}$
Ionizing radiation	Fatal cancers	4×10^{-2} $(Sv)^{-1}$
Benzene	Leukaemia	6×10^{-6} $(\mu g \cdot m^{-3})^{-1}$
Asbestos	Lung cancer, mesothelioma	2×10^{-1} $(fibre \cdot cm^{-3})^{-1}$

[a] For chemical substances, the risk coefficient is the lifetime risk associated with an exposure over a period of 70 years, 24 hours a day and during the whole year at the unit of concentration.

for radiation and the selected substances. Results are presented in Table V. For nickel, arsenic, benzene and asbestos, the 'exposure limits' are expressed as the average exposure value (AEV) which allows for the protection of a worker from health effect [10]. It is measured on the basis of a work day of 8 hours. This value can be exceeded during a short period if it stays lower than the exposure limit value (when this value exists), which is calculated on a maximum duration of 15 minutes.

Given the lifetime risk coefficients presented above, the calculation of the lifetime risk of cancer associated with an exposure at the AEV over a period of 35 years is made with respect to the lifetime risk coefficient estimated for 70 years of continuous exposure; the actual duration of occupational exposure being calculated on the basis of 8 hours a day, 240 days per year, over 35 years. The formula adopted is the following:

$$\text{Lifetime risk} = \text{AEV} \times \text{risk coefficient} \times (35\ \text{years}/70\ \text{years}) \times (240\ \text{days}/365\ \text{days}) \times (8\ \text{hours}/24\ \text{hours}).$$

The lifetime risk of occurrence of a cancer associated with the occupational exposure at the exposure limit of the selected chemical substances over a period of 35 years ranges between 0.2×10^{-2} and 4.4×10^{-2}. It should be noted that this risk includes fatal and non-fatal cancers. The lifetime risk of a fatal cancer associated with occupational exposure to radiation at the annual limit of 20 mSv (2.8×10^{-2}) falls within this range. This confirms that the levels of protection concerning chemical carcinogenic substances and radiation are not fundamentally divergent as is often claimed. This ranking of risk should, however, be confirmed by a comparison of the risk levels associated with the average actual exposure levels in the facilities dealing with the above substances. This is an area which certainly deserves being examined in more detail in the future.

TABLE V. LIFETIME RISK ASSOCIATED WITH EXPOSURE TO OCCUPATIONAL LIMITS

Substance	'Exposure limit'[a]	Lifetime risk for occupational exposure over 35 years
Nickel (plus nickel compounds)	1000 $\mu g \cdot m^{-3}$/8 h	4.4×10^{-2}
Arsenic	200 $\mu g \cdot m^{-3}$/8 h	3.3×10^{-2}
Ionizing radiation	0.02 Sv/a	2.8×10^{-2}
Benzene	16 000 $\mu g \cdot m^{-3}$/8 h	1×10^{-2}
Asbestos	0.1 $(fibre \cdot cm^{-3})^{-1}$/8 h	0.2×10^{-2}

[a] For chemical substances, the exposure limit is the AEV which allows protection of a worker from health effect. It is measured on the basis of a work day of 8 hours.

6. CONCLUSION

The use of quantitative indicators is one way of comparing risks associated with various activities and putting them into perspective. The terms 'annual risk of death' and 'lifetime risk of death' adopted in this paper are the most commonly used for this type of exercise. Other indicators, for example, the loss of life expectancy, could have been selected and bring a further factor to the comparison. For example, the loss of life expectancy related to a cancer is in the order of 15 years and this would apply roughly to both radiation and chemical induced cancers, but the loss of life expectancy for fatal occupational accidents is about twice this figure (it was 35 years in France according to 1999 statistics on occupational accidents [3]). It is certainly useful to take into account such factors in a broader perspective of risk comparison.

Beyond these considerations, the figures presented above show that the average level of radiation risk in the workplace is in the same order of magnitude as other risks to workers. This average level follows the general trend in the reduction of risk at work in all sectors of the economy and reflects the ongoing effort within the nuclear industry and the medical sector to constantly improve the control of exposure. Retrospectively, this rather comforting situation validates the choice made in the late 1950s to adopt a prudent and practical approach for the control of exposure because of the uncertainty as regards the risk associated with low doses.

The comparison also points out that, at upper levels of individual doses, particularly in the neighbourhood of the present occupational dose limits, the level of risk is deviating significantly from the main trends as far as risk estimates for other industrial activities are concerned. This calls for the need to pursue efforts to reduce further the exposure of the most exposed workers in all domains. This can be notably achieved through maintaining efforts in the implementation of ALARA and extending the use of ambitious design and operational dose targets. As was underlined by

C. Meinhold nearly a decade ago, the careful examination of the risk associated with exposure stresses that "the dose limits themselves are entirely unsatisfactory as a basis for designing a protection system and that optimisation should be the focus of our efforts" [11].

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RAPPORTEUR SUMMARY

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1. INTRODUCTION

This paper summarizes the nine presentations comprising Topical Session 1 on Radiation Risks in the Workplace in Perspective. The first four papers in this summary address general topics on control of radiological risks. The remaining five papers are presentations of results from governmental occupational radiation dosimetry programmes in Albania, Guatemala, Poland (two papers) and Tanzania, which discuss reasons for generally decreasing trends in individual and collective doses over time.

2. SUMMARIES

Deboodt [1] expresses a desire to limit radiological and non-radiological risks through generalization of the optimization principle while concurrently giving appropriate consideration to the justification principle. The overall welfare of workers should be protected through a multidisciplinary approach of controlling radiological and non-radiological hazards. The author states that the ‘as low as reasonably achievable’ (ALARA) approach has “increased the level of protection against the radiological risks.” Health physics professionals should be concerned about possible ‘conventional’ risks and the author uses an example where radiation workers are charged with asbestos removal. The paper presents the conclusions of the 4th Workshop of the European ALARA Network which was held in April 2000. The recommendations of the workshop included the need for a common risk management culture, with education beginning in schools and discussions continuing among workers, management, regulators, the media and the general public. Such discussions need to be based on risk management regulations that are clear and transparent. Transference from occupational to public and ecological risks requires careful management as well. Stakeholder involvement in decision making is a necessary element for broad acceptance.

Liebenberg and de Beer [2] discuss relative risks in developed, developing and undeveloped agricultural countries. These authors discuss the need to recognize the interface between occupational and societal risks, and make the case for an adaptable system based on local conditions. Their conclusions point to the need to dedicate resources where the most public benefit can be achieved. Their Fig.1 displays the relationship between the per capita gross national product and mean life expectancy of resident populations. Even within countries, overall health risks, as measured by the age specific probability of death, may vary substantially depending on cultural factors. HIV-AIDS deaths in South Africa are given as an example. Some African countries report infection rates for HIV as high as nearly 40%. In public health terms, resource allocation should be appropriately managed among primary prevention, secondary medical screening and early intervention, and tertiary treatment of disease. The work place, as is also suggested by Deboodt [1], may be a desirable location in which to undertake risk management education on societal as well as occupational risks within countries.

Kumazawa [3] reports a control feedback statistical model consistent with overall reduction of occupational ionizing radiation exposures since the 1940s. Resource allocation to controls are greater for higher doses than for lower ones. The author developed the statistical model for the effect of controls and demonstrates that reductions in individual doses occurring over time are related to lower maximum permissible doses as recommended by the International Commission on Radiological Protection. Greater emphasis on controlling higher dose potentials within ALARA programmes resulted in the Gaussian distributions of annual doses for exposed worker populations shifting from lognormal to hybrid lognormal. The author estimates the degree of feedback control which is dependent on the portions of the distribution in the two regions as well as at the interface between them.

Kutkov et al. [4] indicate that source control is used as the basis for limiting radiation exposures in the Russian Federation. The principles of radiation protection in the Russian Federation are to limit stochastic health effects to an acceptable level by keeping exposures ALARA, protect the general public from ionizing radiation exposures, prevent operational accidents and reduce the consequences of any such accident, and enforce legal requirements, regulations and organizational measures in State laws. The specific rules are applied to human made, human made natural and natural sources of radiation. Depending on the type of source, design and operational requirements have been adopted to prevent loss of control. Sources are considered to be under control when the exposures are maintained below annual equivalent or effective dose limits.

Dollani et al. [5] describe the results of personnel dosimetry in Albania over the period 1996–2001. About 300 of the estimated 800 radiation workers are currently monitored, mostly in principal cities of the country. An upward trend in the number of workers monitored is apparent between 1997 and 2001. In contrast, the mean annual dose has decreased consistently over this same time period from 2.53 mSv to 2.0 mSv. This decreasing trend is attributed to enhanced radiation protection. The use of some older X ray machines and involvement of new workers are stated to have substantially influenced the mean dose. Participation in the IAEA's regional and national Technical Co-operation projects has assisted in the founding and functioning of occupational radiation protection in Albania. This programme should continue to benefit workers and reduce overall exposures, according to the authors.

Guillen [6] reports on the use of personnel dosimetry for ionizing radiation in Guatemala. The author reports a decrease in collective dose in 2000 for workers exposed during medical diagnostic radiology. This decrease was due to increases in licensing procedures, training of users and supervision. On the other hand, in both nuclear medicine and radiotherapy, increases in collective dose over the period 1998–2000 were observed. Industrial and other radiological applications contributed small portions to the overall dose for all workers in Guatemala. The collective dose for workers in the industrial sector displayed small increases for the years 1997–2000. Two technicians using X ray fluoroscopy were exposed to greater than 2 mSv per month owing to faulty equipment and an order was issued to the licensee to repair the device. The trend of increasing collective dose was ascribed to increasing numbers of exposed workers. Mean or median doses for monitored workers were not provided.

Jankowski et al. [7] report on occupational X ray exposures among Polish workers over a 34 year period ending in 2000. The overall mean annual individual dose for all monitored workers in 2000 was 0.54 mSv. Ninety-eight per cent of all readings were less than 1 mSv but two individuals each received a dose that exceeded the annual limit of 50 mSv which equates to a substantial decrease from the 88 (5%) individual annual doses that exceeded this limit in 1966. Approximately 31 000 workers were monitored by this programme in 2000.

Koczynski and Jankowski [8] report the results of dosimetry measurements for workers exposed to nuclear radiation in Poland. These workers are employed in general industry (39%), medicine (26%), education and research (23%), and in the nuclear industry (11%). Monitoring is left to the discretion of the facility where it is certain that annual doses will not exceed 6 mSv. Monitoring is required for facilities where annual doses might exceed this limit. Values below the minimum detectable limit are recorded as zero. An exception report is sent to the employer when a single period result exceeds 5 mSv and is sent to the radiation protection surveillance unit and the regional sanitary inspector when a single period result exceeds 25 mSv. The mean annual individual dose for 5914 workers in all sectors was 0.24 mSv. The general industry sector had a mean annual individual dose of 0.44 mSv. Less than 2% of all monitored workers received doses in excess of 1 mSv in 2000.

Muhogora et al. [9] discuss the results of the Tanzanian radiation monitoring service which has operated since 1986. The service monitors about 1200 workers throughout the country. The report is a thorough summary of dose distributions for the years 1995–1999. During this period, approximately 13% of the monitored workers received doses greater than 10 mSv. Overall, the highest mean annual doses were observed for workers in diagnostic radiology or in education and research. In comparison with the previous five year period, although the individual doses appear to be decreasing the collective dose is increasing. The authors recommend that retrospective dose reconstructions be used to assess radiation risks among potentially exposed workers.

3. CONCLUSIONS

All of these presentations discuss continuing efforts to control occupational radiation exposures. The emphasis is generally placed on control of higher magnitude exposures within the monitored populations of workers. At the same time, many authors appropriately note concerns about greater collective doses that are observed as a result of increasingly effective dosimetry programmes. As radiological technology continues to be applied in more and more sectors of the world economy, reflected particularly in the major increases that have recently been seen in medical diagnostics and therapies, so the need for better source control, optimization of practices and justifications for exposures is likely to require even greater emphasis.

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TOPICAL SESSION 1

DISCUSSION

ZIQIANG PAN: I would like to thank J. Lochard for his presentation and D. Utterback for making a very good review and summary of the session. I agree with their comments. I would like to give my view on aspects of radiation risk in the workplace that should receive more attention, citing examples as appropriate. The radiation risk in underground mines and workplaces should be considered carefully. Taking the Chinese situation as an example, the average annual individual dose for workers at underground non-ferrous mines approaches 20 mSv. The average annual individual dose for workers at underground coal mines is 5 mSv. The total number of workers engaged underground is nearly 10 million. Radiation techniques are being rapidly developed in the field of nuclear medicine. The individual dose to physicians resulting from some of these techniques might be higher, e.g. in interventional nuclear medicine.

The exposure of women of childbearing age among aircrew should be considered.

As regards potential dose control, it was found from the accidents that occurred that the people exposed did not wear personal dosimeters. Therefore, personal monitoring should be stressed.

Radiation risk in the workplace is only one of several risks; various risk factors should be considered during risk control. It has been proven in practice that ALARA is one of the best methods of risk control, and also has many uses outside radiation risk control.

J. LINIECKI: With regard to J. Lochard's presentation, I welcome the efforts being made to compare the dose limits for various noxious agents, but I feel that they obscure matters to some extent. In order to be valid, the comparisons should relate to actual situations in industries or occupations where exposures to various carcinogens occur. Then, the comparisons would not be so bad since the relative impact of radiation is rather low.

In my opinion, there is a further problem. Comparisons of fatal accidents with chronic exposures to ionizing radiation are, in my view, somewhat misleading, as the average lifespan shortening due to fatal accidents is much greater than that due to cancer induction, which occurs almost exclusively at advanced ages.

I believe that the situation regarding occupational radiation exposures is not too bad, when compared with the situation regarding occupational exposures to other carcinogens, particularly as occupational radiation exposures are declining steadily, except in certain medical and other areas where new technologies are being introduced.

J. LOCHARD: J. Liniecki is right; one has to make assumptions very clear when doing comparison exercises. For example, to estimate the average annual risk, we first calculated the the risk related to 35 years of exposure and then divided by 60 years, instead of just multiplying the annual dose by the risk coefficient. This sort of assumption is obviously impacting the result of the comparison.

We had great difficulty in finding an exact average occupational exposure for chemicals as there is no body similar to UNSCEAR in the chemical field. There are a great deal of data, but you can spend a lot of time looking for a number about which you feel confident. That is why we focused on the limit and not on the average exposure associated with actual situations in the chemical industry.

The exercise described in my presentation showed quite a good average trend; in line with what one finds in other branches of economy. My concern relates to the upper end of the dose distribution; for doses above a few tens of millisieverts, the risks are quite high compared with those in other fields. That was the key message of my presentation.

L. PERSSON: If you use UNSCEAR collective doses and ICRP risk assessments for occupational exposure, you get 785 cases of death and illness per annum. Worldwide, about 330 000 fatal injuries per annum are caused by accidents at work, and ILO data indicate that the number of work related accidents and illnesses per annum is more than 1.3 million. These numbers give some idea of the relative importance of occupational radiation exposures as a health hazard, which is low.

A.S. TSELA: J. Lochard concluded that the average risk due to ionizing radiation is not out of line with the average risks due to other hazards. How would that conclusion stand up if one considered exposures to NORM rather than to radiation from nuclear power plants and other situations typical of developing countries?

J. LOCHARD: That is a pertinent question. The purpose of my keynote presentation was to stimulate discussion and I focused on the average situation in developed countries mostly because of a lack of other information. It would be interesting to look at specific situations in different countries.

Regarding the comment made by L. Persson, another way to illustrate the situation is to look at the potential contribution of radiation to the annual mortality. If you take France for example, there are about 500 000 deaths per annum. If one uses the ICRP risk coefficients, one arrives at a few thousand cancers possibly due to all sources of radiation, and of these just two or three due to radiation in the workplace.

G.A.M. WEBB: I feel that we are focusing too much on one particular indicator — average doses. It is easy to manipulate an average dose; one can do it simply by incorporating additional people into the workforce. Together with average dose, we need to consider workforce size and collective dose trends.

Some years ago, UNSCEAR introduced a further indicator — the number of workers or the fraction of the workforce receiving doses in excess of a particular average.

In my opinion, we need to use several indicators, and we should not forget that a higher collective dose may not be a bad thing in certain situations, for example, where a beneficial practice in the medical field is expanding and involving more and more medical workers.

In trying to reduce average doses, we must not ignore other considerations.

R.H. TAYLOR: In the mid-1980s, within the ICRP framework, the late Professor Sir Edward Pochin did extensive work in trying to develop an ‘index of harm’. That work, which seems to have been largely forgotten, could be a useful basis for comparing different types of risk and I would like to see it re-examined with a view to its being taken further.

R.T. LOUW: On the basis of the data in Appendix C of ICRP Publication 60 and a 20 mSv/a occupational exposure, the most probable age at attributable death is about 68 years. The life expectancy at birth in a developing country such as South Africa is about 48 years, which suggests that some of the ICRP data should be recalculated for other countries.

If you use loss of life expectancy as a measure, you obtain figures that are completely different from those presented here and the total risk in comparison to the other risks declines dramatically. Someone who has a fatal accident in the workplace at an average working age of, say, 40 years suffers a loss of life substantially greater than someone who dies at the age of 68 years when he would have died at the age of 69 years from natural causes.

In connection with a mining operation in South Africa, we performed calculations using loss of life expectancy as a measure. We ran a Monte Carlo simulation based, on the one hand, on radiation exposure assumed to be 20 mSv/a for the total number of people employed by the mining company over the total life of the mine and, on the other, on published data relating to transport accidents, underground mining accidents and chemical processing accidents in South Africa (the mining operation has a substantial chemical processing component). When we added up all the risks expressed in terms of loss of life expectancy we found that transport accounted for about 50% of the total risk, with underground mining and chemical processing accounting for about 25% each. Assuming that every individual employed by the mining company over the life of the mine was exposed to 20 mSv/a, radiation exposure accounted for only 2% of the total risk. If we had used the risk factors indicated by J. Lochard, the picture would have been completely different. I think it is important that regulators, when setting standards and imposing them, especially on companies operating outside the nuclear power sector, bear such things in mind.

J. LOCHARD: As I indicated in my presentation, it is possible in this area to do anything one wishes with the numbers; if one wishes to demonstrate that nuclear power or ionizing radiation is safe or, on the contrary, dangerous, one can find numbers which will permit that. We used risk coefficients and averages, without maximizing the results and we applied them coherently to all the sectors we compared. It is obvious that if we had used life expectancy as an indicator the results would have been different.

Of course, life expectancy is mentioned in publications of the ICRP, but so are comparisons of the probability of death in different fields of economic activity. In ICRP Publication 26, it was stated that the limit had been set in such a way that the level of risk to workers would be among the risk levels in those fields where the standards of safety are high. In ICRP Publication 60, it is stated that the dose limit is a ceiling above which the consequences for the individual would be seen as unacceptable.

Consequently, in my opinion it is legitimate to use these numbers for comparison purposes if one bears in mind that a worker is unlikely to contract cancer at the age of 25 years but may well fall off a ladder at that age. I do not like the argument that the entire complex picture becomes invalid if one uses other numbers.

R.T. LOUW: In fields such as actuarial science and environmental economics, a great deal of work has been done on calculating risk. In my view, radiation protection professionals should examine the substantial body of literature resulting from that work.

S.C. PERLE: Further to G.A.M. Webb's comment, which I endorse, I would say that in the USA there are probably some 100 million people who are, from time to time, monitored for radiation exposure and that about 70% of these people receive no measurable doses. What is the meaning of ALARA in such a situation?

In my opinion, we should focus on those occupations where the workers are exposed to ionizing radiation and on the variations in the exposures. There is no point in considering workers who are not occupationally exposed. The money should be used where there really is exposure.

S. VAN DER WOUDE: Many developing countries face major challenges in trying to balance the risks involved in various non-nuclear industries.

In my view, the IAEA, which has a very laudable programme for helping developing countries establish radiation protection infrastructures, should, as part of that programme, provide guidance on how to integrate radiation protection and the balancing of risks into the overall national health protection and safety arrangements. Such integration does not occur if there are regulatory bodies focusing exclusively on radiation protection.

In saying this, I am, of course, aware that at present the provision of such guidance lies outside the IAEA's remit.

C.J. HUYSKENS: In my view, it is important for us to assist workers in comprehending what 'radiation risk' means, and in that connection I recall the International Conference on Radiation and Society: Comprehending Radiation Risk held in Paris in October 1994, which the IAEA organized and the proceedings of which it published.

Workers in a wide variety of industries need to know what the radiation risk means as far as their safety at work is concerned, and they must be provided with trustworthy information about the level of radiation safety in their respective occupations.

M. BOURGIGNON: There is a distinction between two types of occupational risk figure which I think we should always bear in mind. Occupational risk figures for accidents not involving ionizing radiation exposure are based on accident statistics (for example, the number of workers who died in occupational accidents in a particular industry over a given period), whereas occupational risk figures for accidents that do involve ionizing radiation exposure are based on probability estimates.

G.G. EIGENWILLIG: I was disturbed by the reference of S. van der Woude to the balancing of risks and by the following sentence in paper IAEA-CN-91/92 submitted by G.P. de Beer and a colleague, both also from South Africa, “According to the South African press the risk of being murdered in the country is currently 6 in 10 000, which is the equivalent of a 12 mSv/a dose.” In my view, it is wrong to compare ‘conventional’ risks such as the risk of being murdered with radiation related risks. High conventional risk levels should not be regarded as a reason for reducing radiation protection.

I.A. GOUSSEV: I have been rather disappointed by this Topical Session, as it has, in my view, focused too much on average risk assessments and not enough on individual risk assessments.

I think the relevant international bodies should develop guidance relating to individual risk assessments that takes into account such facts of normal life as habits and genetic disposition. There are some ICRP publications that might be helpful in that connection.

R.T. LOUW: With regard to G.G. Eigenwillig’s comments, I think that our main concern should be the overall health and safety of workers and that the limited budgets available for health and safety measures should be spent in such a way as to achieve the maximum benefit. If those budgets were unlimited, I would agree with G.G. Eigenwillig and say “Lets push all the limits down to the lowest possible level.” In the real world, however, we have to prioritize the health and safety issues.

Because of the regulatory environment in the radiation protection area, we have to spend substantial amounts of money on risks that do not have a great impact on worker health and safety as a whole. In my opinion, that is wrong.

J.R. CROFT: Further to what G.A.M. Webb said, which I endorse, I would mention that an UNSCEAR publication on occupational radiation exposure which I compiled (UNSCEAR 2000, Volume I: Sources, Annex E) contains data on the basis of which one can derive dose profiles for a particular type of occupational exposure within a given country. I encourage Conference participants to look not only at that data, but also at the associated caveats, since not all of the questionnaires sent out for the purpose of data collection were returned, so that some extrapolating was necessary.

Where the data are plentiful, as in the case of the data relating to human-made radiation sources, I think one can be fairly confident about the figures. However, in the case of the data relating to natural radiation sources — for example, in mining — the caveats should be taken very seriously. We need more data on occupational exposures to NORM, including more data on the occupational exposure of miners in China.

D.F. UTTERBACK: Because of the shortness of the time allowed for my presentation, I focused on average exposures. In the papers which I reported on, there are substantial amounts of data relating to those members of the monitored population who receive doses in excess of the upper values recommended by various groups.

INFRASTRUCTURE DEVELOPMENT

(Topical Session 2)

Chairperson

C. SCHANDORF
Ghana

CULTURAL AND ORGANIZATIONAL ISSUES UNDERPINNING RADIOLOGICAL PROTECTION

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Abstract

There has been an increasing awareness over the last decade that issues relating to the adequacy of management systems, the promotion and maintenance of a good safety culture and the careful management of organizational change are fundamental to ensuring that nuclear and radiological safety are adequately controlled and that a good basis exists to achieve continuous improvement. This paper reviews developments in the context of radiological protection, with a particular focus on the contribution from the International Nuclear Safety Advisory Group (INSAG). It includes some material extracted from recent INSAG publications in this area, which are considered particularly relevant to the theme of the session. The paper begins with a discussion of the cultural and organizational prerequisites for developing and maintaining a good safety culture in operating organizations. This includes a discussion of the organizational requirements for safety which form the 'spine' on which a systematic approach can be developed. It goes on to discuss in pragmatic terms the attributes of a good safety culture and then addresses the vital area of change management. This section emphasizes that during periods of major change — often brought about from pressures arising from the need to be more competitive in deregulated markets — the effects of organizational changes on safety must be just as well controlled as the effects of engineering changes. Finally, the paper considers the requirements for national infrastructure and the role of the regulator in scrutinizing developments in areas relating to management, organizational change and culture. These are important matters but are not always within the established competences of regulators and are less amenable to the application of the mechanisms of regulatory oversight in dealing with technical and engineering issues.

1. SAFETY MANAGEMENT SYSTEM

Organizations having a strong safety culture will have an effective safety management system with the involvement, support and 'ownership' of all the key stakeholders. However, a safety management system has a broader role in that it provides a framework through which an organization can ensure good safety performance. It is generally considered to be an integral part of the organization's quality management system.

A publication of the International Nuclear Safety Advisory Group (INSAG) on Management of Operational Safety in Nuclear Power Plants (INSAG-13) proposes a general framework for safety management [1]. This is reproduced in Fig. 1. Within the operating organization, it comprises four elements:

(1) ‘Definition of safety requirements and organization’ involves the organization determining its policy for safety and specifying the main responsibilities and activities required to ensure safety and to satisfy legal, regulatory and company requirements.
(2) ‘Planning, control and support’ involve the organization determining the arrangements to ensure that the required activities are implemented safely.
(3) ‘Implementation’ involves individuals carrying out their tasks safely and successfully.
(4) ‘Audit, review and feedback’ involve the organization confirming both the achievements of its plans and the application of its standards, and improving safety by learning from its experience and the experience of others.

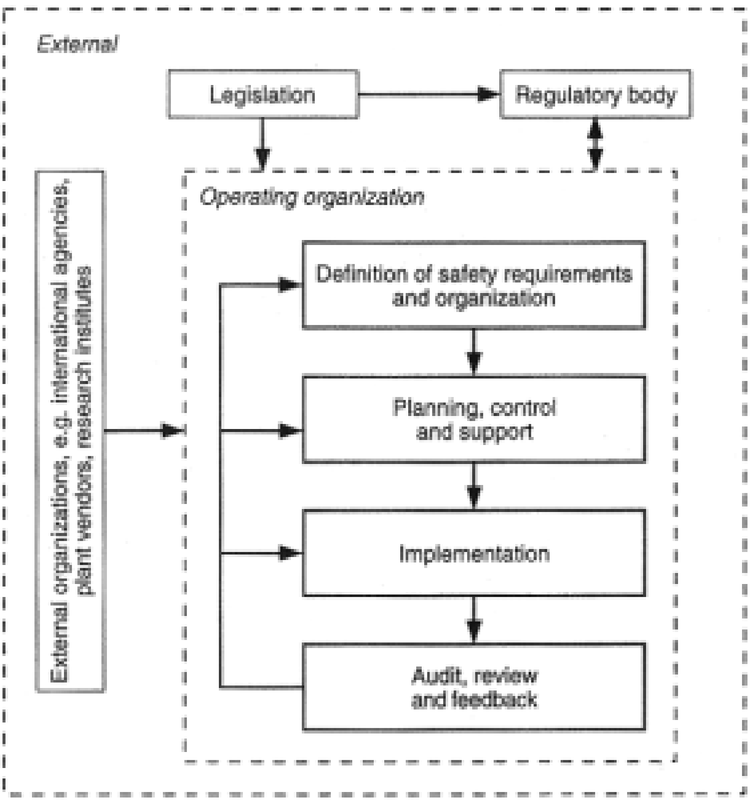

FIG. 1. Framework for safety management.

Figure 2 shows each of these primary components of the management system broken into subareas. These are defined and fully discussed in INSAG-13. It is important that organizations appraise themselves of the adequacy of their systems for

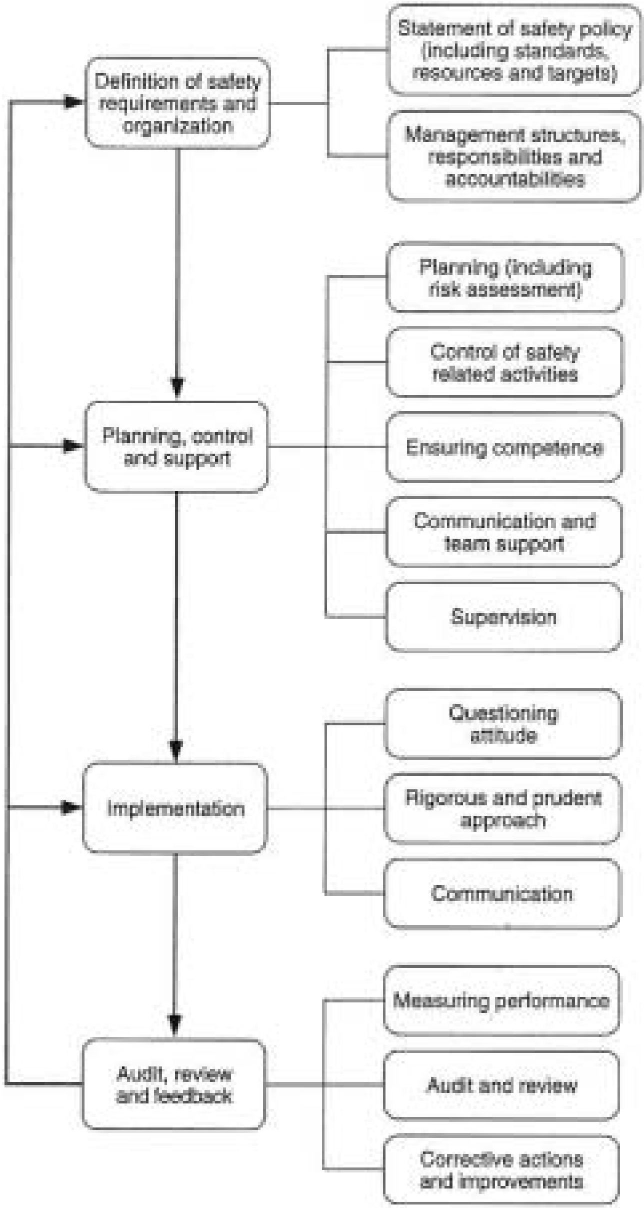

FIG. 2. Management system subareas.

managing safety, competencies and commitment within each of these areas if a high level of safety is to be achieved and maintained, and if safety is to be continuously improved.

Although the approach in INSAG-13 is general in its application, it is highly relevant to radiological protection. For example, in INSAG-13 a series of questions or 'prompts' are developed to assess the integrity of a safety management system. These can be made more specific in order to form the basis of an assessment of an organization's approach to radiological protection. Such questions might include the following:

(a) Does the organization have a clear statement that expresses its policy and its commitment to excellence in radiological protection with associated measures of performance and is this understood by the workforce and actively and visibly supported by senior managers? Is the same true for the supporting safety standards and procedures?
(b) Are the roles and responsibilities within the organization clearly defined and understood, and when changes take place are these managed and controlled so as to ensure that radiological performance is not impaired?
(c) Is there an adequate system for assessing the risks associated with operational tasks, both at the planning stage and at the point of work?
(d) Is there a system to ensure appropriate authorization for both those carrying out radiological protection activities and those providing advice?
(e) Is there a process in place to ensure that staff and contractors are suitably qualified and experienced and backed up by the means to identify individual training needs and provide a training programme to address these?
(f) Is there a system to ensure an appropriate degree of verification and supervision for radiological protection activities and do those supervising activities maintain a visible presence in the workplace?
(g) Is radiological protection performance measured using a range of relevant indicators and are peer review and external benchmarking encouraged, both for specific practices and operations and for the management system as a whole?
(h) Are events used as learning opportunities and is compliance with radiological protection standards independently assessed?
(i) Are there clear, prioritized improvement programmes, sufficiently resourced, involving the workforce in their formulation and implementation in order to maximize commitment and ownership?

2. SAFETY CULTURE

The 'implementation' component in Fig. 2 is expanded by reference to three key attributes of a good safety culture, namely: a questioning attitude, a rigorous and prudent approach, and good communication. These were first formulated and discussed in INSAG-4 [2], which was a landmark publication in thinking about the subject. In practice, the requirements of a good safety culture are not separate entities but permeate all of the ‘process’ issues discussed in INSAG-13 and illustrated through the above questions.

IAEA Safety Reports Series No. 11 [3] identified three stages which typically occur in the development and strengthening of safety culture:

(1) Safety is compliance driven and is based mainly on rules and regulations. At this stage, safety is seen as a technical issue, whereby compliance with externally imposed rules and regulations is considered adequate for safety.
(2) Good safety performance becomes an organizational goal and is dealt with primarily in terms of safety targets or goals.
(3) Safety is seen as a continuing process of improvement to which everyone can contribute.

The foregoing discussion is a simple and idealized representation of what is, in practice, a complex process. In reality, the three phases are not distinct and any organization may have some parts that are ahead of others in the process of strengthening safety culture.

In the first stage, improvements are often primarily gained by improving the engineered safeguards of the plant in line with, for example, the principles contained in INSAG-12 [4], which is the revised version of INSAG-3, and introducing basic systems and procedures to control hazards. These improvements are often driven by the need to meet regulatory requirements and are usually achieved by means of management edict, using professional safety staff to deliver the improvements. Staff members tend to believe that safety is the responsibility of management and is largely imposed upon them by others.

The second stage of development involves the use of a safety management framework (such as that presented in Section 1). At this stage, individual employees will notice that work is better planned, with prior consideration of safety hazards and rules and procedures governing what can and cannot be done and which are systematically documented. However, in many organizations, this stage of safety is still often ‘imposed’ on the individual worker with little involvement or consultation, and is administered and monitored by safety professionals. Although this phase of improvement can raise consciousness about the need to work in a safe environment, it does not of itself gain the commitment to, and identification with, safety at the individual level or the team level.

The third stage of development is the ideal that many organizations are striving to attain. Achieving it is a continuing process. It requires a safety related vision and values that are fully shared. A large proportion of the individual employees in the organization need to be sufficiently committed that they are personally and actively involved in enhancing safety. As appropriate, contractors and others with an influence on safety will also be fully involved. Everyone will have a clear understanding of requirements and aspirations, and individually, or particularly through teams, will show a commitment to achieving and sustaining enhancements to safety in all that they do.

At this stage safety is ‘in the bloodstream’ of the organization. Poor conditions and practices are viewed by all to be unacceptable and are openly challenged. Events and incidents, whether related to industrial safety, environmental issues, or radiological or nuclear safety, are seen not as part of normal working life, but as exceptional and unacceptable occurrences that can be avoided. At this point a learning organization has been created with a self-sustaining safety culture.

It is important that any organization striving to move into the third stage of development does not neglect the earlier stages and the importance of going through them before proceeding to the last stage. Achieving good safety performance requires a rule based, compliance culture and high quality engineering as prerequisites and these need to be strongly maintained even whilst developing the elements more strongly related to the human issues discussed in this report.

Recently, INSAG has attempted to set out the key factors which are important in reaching and maintaining the third stage of safety culture described above. These will be formally published shortly in INSAG-15 [5] but are already available on the IAEA website.[1] A paper drawing out those issues in a simple way for non-nuclear specialists has also recently been published by the author [6]. They may be summarized as follows:

(a) Commitment

Safety is put clearly and unequivocally in first place in the requirements from the top of the organization. However, it goes further than this. It is vital that managers at all levels in the organization ‘live out’ their expectations of others by ensuring that their personal actions match their words. In a radiological protection context, as with other safety issues, it is thus important that ‘managers’ spend time personally looking at safety issues ‘on the ground’, speaking to staff about their views of practices, and performance. One particular test of commitment is that if operations are running behind schedule, is there still an insistence that radiological protection requirements come first, that safety must be maintained and that shortcuts will not be taken, or is a ‘blind eye’ turned to shortcuts?

[1] At http://www.iaea.org/ns/CoordiNet/insag/INSAG15_draft.pdf.

(b) Use of procedures

Procedures are essential. However, they need to address the main risks and be intelligible and of relevance to those who actually have to use them. When considering procedures for radiological protection it is thus important to ask whether those who will use them have been involved or consulted in their preparation and whether the reason for the procedure is understood as well as the potential consequence of not adhering to it. Most importantly, a set of procedures which is not consistently applied by those who use it is largely worthless. Monitoring its usefulness and avoiding the introduction of 'workarounds' is thus vital.

(c) Conservative decision making

One of the key attributes of a good safety culture was recognized in INSAG-4 as being the need for a questioning attitude and a rigorous and prudent approach. This is now often referred to as the need to make conservative decisions. Whilst its application by the individual is vital, the organization's safety culture needs to support and reinforce the approach. Techniques have been developed (such as STAR — stop, think, act, review) which support conservative decision making at the point of work and there is a growing appreciation of the need to carry out risk assessments (and act upon them) both at the planning stage and at the point of work. In a radiological protection context, for example, conservative decision making means that if there is a possibility that an area may be contaminated or that a monitoring instrument could be faulty, steps will be taken to check this before work commences. This may cause delay, but in an organization with a strong safety culture, such caution will be visibly supported by managers, and radiological protection staff will know that this expectation and support are present as part of the organization's basic approach.

(d) A reporting culture

Failures and near misses provide the potential, if reported and acted upon, to avoid more serious events. To encourage this, individuals must feel that they will be fairly treated and not blamed when they report problems or shortcomings and that these will be regarded as learning opportunities rather than opportunities to criticize or blame individuals. This, therefore, involves the development of a 'just' reporting culture by discussion with the workforce and its representatives.

One way to test whether an effective reporting culture has been attained is to measure the number of reports of incidents and near hits (near misses) of varying significance. If a good culture is being achieved, the number of reports, of relatively minor failures, transgressions or near hits will be an order of magnitude or so greater than relatively minor incidents (such as actual contamination or spillages) and these, in turn, will be a further order of magnitude or so more frequently reported than more serious radiological incidents.

(e) Challenging unsafe acts and conditions

Latent or 'hidden' shortcomings in safety systems, procedures or plant conditions are the precursor to nearly all events. In many cases, such shortcomings have existed for a long time, have gone unnoticed or regarded as custom and practice. Analysis of incidents, however, shows that these latent conditions, although perhaps unlikely to lead to an incident when treated as individual shortfalls, can come together when an initiating event occurs and produce a serious incident or accident [7]. It is thus vital that active programmes are in place to seek out and remedy defects and procedural shortcomings. By their nature, this can only be achieved effectively if individuals and teams are given training to develop awareness and understanding of the issues and the confidence to challenge unsafe acts and conditions wherever and whenever they encounter them. This is not just a matter of conducting formal inspections and audits (important though these are), but has to be developed as part of the conscious mindset of the largest possible proportion of the workforce with the support and commitment of management, which makes available sufficient resources to remedy shortfalls in a prioritized, timely way.

There are many examples of these issues in the radiological protection area. Consider, for example, the transport of radioactive materials. Owing to the repetitive nature of the process or the existence of a poor procedure, checks on the integrity of a package may not be adequate. Normally this would not necessarily result in a serious failure. Likewise, monitoring of the package before despatch or during transport may be inadequate (owing, for example, to a faulty monitoring instrument). Again, this would not by itself lead to a serious incident. However, a combination of these shortfalls, together with an initiating event such as a faulty package seal or other defect or a mishap during transportation could lead to a serious, perhaps even life-threatening accident. This combination of individual shortfalls can only be prevented by awareness and 'challenge' at each stage of the process.

(f) A learning organization

Several of the earlier issues relating to safety culture might be seen as part of the concept of a learning organization.

If an organization stops searching for improvements and new ideas by means of benchmarking and seeking out best practice, there is a danger that it will slip backwards. A learning organization is able to tap into the ideas, energy and concerns of those at all levels in the organization. Enhancements in safety are sustained by ensuring that the benefits obtained from improvements are widely recognized by individuals and teams, and this in turn leads to even greater commitment and identification with the process of improving safety culture. Ideally, all employees are involved in proactively contributing ideas for improvement, and are encouraged to become aware of what world class performance in terms of safety means in their jobs. They contribute not because they are *told* to do so, but because they *want* to do so. To do this, they need to be given the opportunity to compare the way they do things with that of other workers, so that they are aware of what constitutes excellence in their field of work. Furthermore, to generate a sense of achievement, they need to be enabled to carry out themselves the improvements they have identified wherever it is safe and sensible for them to do so and with the encouragement and full backing of management.

Processes such as peer reviews by external bodies and periodic safety reviews enable learning to be achieved by listening to the input of others and by 'standing back' to assess practices so that shortcomings do not become established.

In radiological protection terms, one simple example of the application of some of the above ideas would be the involvement of the workforce in seeking the means of reducing doses in particular parts of the plant or during particular activities, perhaps with the assistance of informal peer review. Driving towards the 'as low as reasonably achievable' aim by encouraging teams to discuss and implement their own ideas in a controlled manner and by recognizing and pursuing best practice will not only raise awareness of an important issue, but will lead to real and sustained improvement.

(g) Other issues

INSAG-15 goes on to examine some of the underpinning issues to achieving a good and improving safety culture. These include the need for effective, timely and relevant two-way communication on safety matters, the need for clarity about accountabilities and organizational arrangements — particularly during periods of change and, very importantly, the need to develop plans for improvement which are prioritized, realistic, involve input from the workforce and other stakeholders (such as regulatory bodies) and for which progress is measured and accountabilities for delivery are clear. In pursuing improvements in radiological protection capability, for example, it is vital that a few, well-targeted issues are identified and agreed as priorities rather than developing unsustainable 'wish lists' for improvement which, when not achieved, can breed a culture of low expectations and cynicism.

The Annex considers a practical example of some of the cultural issues underpinning a potentially commonplace event in radiological control — the identification of contamination on an operator on leaving a controlled area. This illustration draws out the potential cultural factors at play, the types of response which might be anticipated and the learning points for those who have responsibility for radiological control in the organization.

3. THE MANAGEMENT OF CHANGE

It is well recognized that proposed technical changes affecting safety must be properly considered in safety terms before being implemented. Consideration of their impact on the radiological protection of the workforce and the public is a vital component in the processes used to assess the proposed changes systematically.

In recent years, however, the need to reduce costs and improve efficiency, together with structural changes to the industry, have meant significant changes in processes, staff numbers and organizational arrangements. An example in the radiological area has been the growing practice of 'buying in' expertise through the greater use of contractors. INSAG has been concerned that senior managers should be fully aware of the need to address the safety implications of such changes.

Significant organizational changes can have beneficial effects on safety, but if they are not carefully considered and planned in advance and their potential impact on safety fully assessed, they have the potential to degrade safety performance. When organizational changes have been made and technical competencies lost, it is often very hard to reverse the change. It is thus important that for potentially significant safety changes:

(a) An implementation plan is drawn up which recognizes the need to scrutinize the effects on safety of the proposed changes as they proceed and which recognizes the circumstances in which countermeasures may need to be applied, should adverse effects become apparent.
(b) The position at the end of the change is defined and its implications for safety performance fully assessed. In particular, it is important to ensure that provision has been made to maintain a suitable level of trained and competent staff in areas critical to safety (such as radiological protection). Part of the process will involve documenting new systems with clarity about roles, accountabilities, interfaces and the need for retraining.
(c) It is equally important that the transition to new arrangements be acceptably safe. For example, safety critical expertise needs to be maintained until it can be shown that the required competencies exist elsewhere and that the appropriate transfer of plant specific technology and practices has been completed.
(d) For engineering changes, it is good practice to classify changes as to their safety significance and to ensure that the significance is matched by a commensurate level of oversight both from within the organization and from regulators. The same principle can be applied with good effect to organizational changes.

In radiological protection, the maintenance of competence is a particularly important issue. To obtain and retain the necessary qualifications and experience, particularly in some specialist areas, means that for organizations (operators, designers and regulators), it is important that there is a formal process to ensure that those carrying out important safety related tasks are suitably qualified and experienced and that forward planning is carried out to ensure that in key specializations, the succession arrangements for trained and competent staff are identified and developing shortfalls identified at a sufficiently early stage.

4. IMPORTANCE OF NATIONAL INFRASTRUCTURE AND THE INDEPENDENCE AND ROLE OF THE REGULATOR

Radiological issues and real events can now arise in almost all countries in the world. Experience has shown that events arising from the incorrect operation and disposal of sources used for medical treatment or industrial application have been the source of more serious injuries to workers and the public than those arising from nuclear power production or its associated fuel cycle. It is thus vital that all countries using radioactive materials develop a governmental and regulatory infrastructure to control and regulate the use of such materials. INSAG recognizes the need for independence in regulatory decision making and makes the point that regulatory bodies have three basic functions: (1) to develop and enact a set of appropriate, comprehensive and sound regulations; (2) to verify compliance with such regulations; and (3) in the event of a departure from licensing conditions, malpractice or wrongdoing by those regulated, to enforce the established regulations by imposing the appropriate corrective measures.

The performance of these functions must be entrusted to a regulatory body provided with adequate authority, competence, and the financial and human resources recessary to discharge its assigned responsibilities. Moreover, in order to ensure independence in exercising these basic regulatory functions, there must be an effective separation between the functions of the regulatory body and those of any other body or organization concerned with the promotion or utilization of sources. It is not only important that regulators have the necessary technical knowledge about the nature of the materials, associated hazards and effects of radiation together with well-established and well-understood administrative controls, but also vital that regulatory bodies promote effective safety management systems and improvements in safety culture, and scrutinize the effectiveness of the operator’s or user’s systems and approach. To accomplish these tasks effectively in these organizational and cultural areas requires a delicate balance to be struck. By their very nature, many of the issues addressed in this paper relate strongly to management responsibilities and processes and, in some cases, fields of expertise which regulatory bodies may be less equipped to deal with than more ‘conventional’ areas relating to science and engineering. INSAG has made the point that whilst the issues in this paper are properly addressed by regulatory bodies, they should be careful not to exercise direct control or undue influence on the management of safety or impose detailed requirements on the form of the operating organization's safety management system or its approach to safety culture. This would be counterproductive in that it may weaken the system of self-regulation and diminish and dilute the responsibility for safety assumed by the operating organization, as well as potentially introducing bureaucratic requirements which slow changes where these are both necessary and justified in safety terms. INSAG has stressed that regulators need to confine their involvement to *safety* management, and in particular to ensure that the operator has the appropriate mechanisms in place for self-assessment of the safety management processes.

5. CONCLUSIONS

Adequately addressing the organizational factors and the 'people issues' affecting safety is as vital to maintaining excellence in safety performance as is the need to address the safety implications of engineering and technical matters.

This paper outlines, with particular reference to radiological protection and by using recent INSAG publications as source material, the need to address the following issues:

(a) The development of a safety management system following a recommended structure;
(b) The key requirements in developing and maintaining a good safety culture;
(c) The need to manage organizational change in a systematic and controlled way;
(d) The need for regulators and other supporting technical bodies to make informed judgements on these issues, but to do so in a way which does not unnecessarily constrain changes and which does not take responsibility from operators in assuring that they are operating safely.

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Annex

HYPOTHETICAL EVENT

At the end of a shift, whilst in the changeroom, an operator finds that he/she has contamination on hands and clothes. This may be a ‘simple’ isolated event, but it may also provide signals of underlying issues — particularly if the event is a repeat event or if the responses below indicate inappropriate behaviour.

Cultural factor	Response to incident	What may need to be done to reinforce safety culture
Commitment	Operator attempts to ignore the contamination	Company needs to reinforce clearly the message that contamination is an avoidable and generally unacceptable consequence of carrying out work, in line with the high standards that it sets for health and safety generally.
Use of procedures	Operator does not know what to do or does not follow procedures for decontamination	There needs to be absolute clarity about why following the procedures is vital. Their relevance, appropriateness and ease of understanding should be checked with the involvement of those who use them and any lessons learnt.
Capability	Relevant people did not have sufficient knowledge	The requirement for being suitably qualified and experienced is understood and reinforced. Shortfalls in knowledge and understanding are addressed by training and coaching in a wider context.
Conservative decision making	Operator did not have or apply an adequate risk assessment or carry out sufficient self-checking	Requirement should be made clear on the need for work areas to be checked and that appropriate PPE be worn both before setting people to work and at the point of work (even where this may slow down the work).
Reporting culture	The event is not reported or the report is ignored/not acted upon	Simple to use systems should be available for reporting, the importance of learning from near misses is made clear and that there is a thorough, timely and transparent follow-up to such reports with teams involved and helping to implement changes.

Cultural factor	Response to incident	What may need to be done to reinforce safety culture
Challenging unsafe acts on conditions	It was well known that contamination in the area could occur, but nobody could be bothered or had time to deal with it	The risks, time and trouble involved in the event could have been avoided for everybody if action had been taken in advance. The organization demonstrates that it backs and encourages those who challenge poor or unsafe conditions and acts on their efforts. It resolves any time or resource pressures and makes clear the need for safety to take precedence.
Learning organization	The event may be reported and local remedial action taken, but lessons are not promulgated	The organization demonstrates that it uses incidents to assess wider learning points. Questions are asked and addressed such as: Where else could it happen? What do others need to know about the event? Are there similar (not necessarily identical) situations in which lessons could be learnt and used? What were the *real* causes?
Communication	There were difficulties in dealing with the event because of poor two way communication. Despite good intentions, other potentially affected people did not hear about the lessons learnt from the event.	The lessons are learnt and communicated in a useable intelligent form and *not* just for events of this exact type. The understanding of others who need to know is regularly checked and the adequacy of communication channels (e.g. team briefings) reviewed and improved.
Organization	The worker did not know who was responsible for various issues uncovered during the event	Clarity about accountabilities (particularly during or after change) is checked and, if necessary, remedial action taken to ensure these are understood, ‘owned’ and underpinned by a change process. Procedures are also clear on where accountabilities lie.
Prioritization	Radiological protection issues are receiving insufficient time and attention and/or actions for improvement are not being satisfactorily completed	The organization tries to understand whether this is symptomatic of a wider shortfall. It assigns clear priorities to actions and has clear accountabilities and processes for checking completion of the actions required.

RAPPORTEUR SUMMARY

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1. INTRODUCTION

The IAEA requirements publication Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety[1] specifies requirements on the various elements of national infrastructure that have to be established. Although the document is therefore not restricted to infrastructure for occupational exposure, many of the elements are applicable to occupational exposure. These elements would hence be used for the structure of this summary. Under each element a number of key observations have been highlighted and followed by possible points for discussion.

The pace of infrastructure development is often strongly dependent on the resources available in the country. To understand the context associated with the papers related to infrastructure development, it is therefore useful to have an understanding about the countries from where these papers originate. For this purpose the World Bank Country Classification was used. The results are presented in Table I.

TABLE I. THE COUNTRIES FROM WHICH PAPERS ORIGINATE CLASSIFIED ACCORDING TO COUNTRY INCOME GROUP

Country income group	Papers assigned to each group
Low income	21%
Middle income	50%
High income	29%

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Legal and Governmental Infrastructure for Nuclear, Radiation, Radioactive Waste and Transport Safety, Safety Standards Series No. GS-R-1, IAEA, Vienna (2000).

Many countries, particularly those with a strong developing component, acknowledge the valuable role that the IAEA plays in the development of their infrastructures. Some of the discussion points in this summary therefore relate specifically to this role of the IAEA and how it could be strengthened.

2. LEGISLATIVE AND GOVERNMENTAL RESPONSIBLITIES

Generally, legislation in respect of occupational radiation protection has been established in all countries that submitted papers.

One area of concern is that very few papers mention that exposures due to natural sources or naturally occurring radionuclides are included in the scope of their legislation. This is the case, despite the fact that two of the papers indicate the importance of this exposure in the broader occupational exposure context. The one paper, for instance, quotes the Conference's Announcement and Call for Papers that "Less than half of the occupationally exposed workers are exposed to artificial radiation sources. The remainder are exposed to elevated levels of natural radionuclides." Another paper mentions that 43 out of 79 workers exceeding 20 mSv during 2000 were uranium miners.

Although the risk of fatal exposures from artificial sources is clearly a major concern, activities that involve occupational exposure to naturally occurring radioactive material (NORM) could in many developing countries constitute the highest occupational exposure if one only considers normal operations. This fact should be taken into account in establishing priorities for the implementation of an occupational exposure infrastructure.

Discussion point: NORM (technologically enhanced NORM (TENORM) exposure)

Exposures to NORM (including TENORM) in facilities such as mines could in many countries be the highest occupational exposure hazard arising from normal operations. How should control of exposure to NORM be incorporated in the legal occupational exposure infrastructure and subsequent regulatory programmes?

3. RESPONSIBILITIES AND FUNCTIONS OF THE REGULATORY BODY

Few papers focus specifically on the responsibilities and functions of the regulatory body. From most of the papers, it appears, however, as though the legislation provides regulatory bodies with the authority to conduct the essential regulatory functions. A number of papers present the difficulties of having limited resources and balancing radiation risks with other risks in a developing country.

Discussion point: Type and level of guidance for developing countries

What guidance would be useful to developing countries on the minimum resources required to implement an occupational exposure infrastructure and on balancing radiation risks with other occupational risks?

4. ORGANIZATION OF THE REGULATORY BODY

GS-R-1 states that “The regulatory body’s reporting line in the governmental infrastructure shall ensure effective independence from organizations or bodies charged with the promotion of nuclear or radiation related technologies, or those responsible for facilities or activities.” Less than 30% of all the regulatory bodies mentioned in the papers neither report to a national nuclear energy agency nor to a department of health and may, therefore, be in conflict with the above requirement. This is particularly the case in the developing countries.

GS-R-1 also states that “If the regulatory body consists of more than one authority, effective arrangements shall be made to ensure that regulatory responsibilities and functions are clearly defined and co-ordinated…” A number of papers mention the importance of co-operation amongst regulatory bodies which may have shared responsibilities in the area of occupational radiation protection.

Discussion point: Independence of the regulatory body

The limited radiation protection expertise existing in many developing countries and political complications could lead to serious difficulties in establishing an effectively independent regulatory body early on in an infrastructure development programme. This may lead to delays which impact adversely on the protection of workers. What is the appropriate priority in the establishment of a national legal infrastructure for ensuring that the regulatory body is effectively independent, i.e. is it more urgent to establish a regulatory body regardless of the reporting line or is it more important to establish a regulatory body that is effectively independent?

5. ACTIVITIES OF THE REGULATORY BODY

5.1. Authorization and review and assessment

In terms of authorization, the papers indicate that most countries have undertaken a notification exercise to establish an inventory of sources. Very few papers deal with the authorization process and only one paper elaborates extensively on the licensing of sources and the associated review and assessment.

The papers from developing countries indicate that many sources have to be authorized retrospectively and one paper highlights the specific difficulties associated with retrospective licensing.

5.2. Inspection and enforcement

One paper presents a very detailed practice specific inspection checklist highlighting the advantages of having such checklists.

Some of the papers indicate the difficulty with enforcement, particularly in the early phases of implementing a regulatory programme. One reason may be that holders are not aware of what has to be done; another may be that they do not understand why they have to change the way in which things have been done in the past.

5.3. Development of regulations and guidance

At the requirements or regulations level papers refer to the International Basic Safety Standards and/or the related Euratom Directive. The only deviation was a paper which indicates that a dose limit of 50 mSv is at present included in model regulations on NORM.

At the guidance level, a number of papers refer to facility (practice) specific type publications such as IAEA TECDOCs. This is a clear indication that such a type of publication is beneficial to users.

5.4. General

More papers elaborate on inspection activities and the development of regulations and guides rather than on authorization and review and assessment. This is not surprising given the developing nature of many of the regulatory programmes that are described in the papers.

Discussion points: Type and level of guidance for developing countries

Retrospective licensing poses considerable challenges to a regulator. The users are generally not well trained in radiation protection and would question the need for licensing, particularly if it entails additional costs. The guidance of the IAEA generally assumes prospective licensing. What guidance should be provided on retrospective licensing?

There is a school of thought that argues that detailed review and inspection checklists may misdirect the focus of the regulator and as such lead to an oversight of major safety concern. In countries with limited resources, the availability of such standardized checklists may however assist in 'fast-tracking' the implementation of an occupational exposure infrastructure. Should more detailed facility (practice) specific review and inspection checklists be developed for developing countries?

It is generally assumed that the regulatory authority would translate the more general IAEA documentation into regulations and/or facility (practice) specific guide documents. In countries with limited resources this may present a considerable challenge to newly established regulatory authorities. Should more detailed facility (practice) specific guidance be developed for developing countries?

6. SERVICES

6.1. Training and education

Training and education is a critical component to the development and implementation of infrastructure related to occupational exposure. A number of papers, particularly those from developing countries, indicate that the regulatory body provides training to holders of authorizations.

One paper suggests interesting new performance indicators for training. These are based on the premise that it is more important for training to result in a change in behaviour than in good examination results.

A number of papers highlight the advantages of:

(a) Standardization in training;
(b) Distance learning, particularly through the internet;
(c) A strong practical orientation to training, including short courses focused on specific applications/facilities/practices.

Discussion points: Mechanisms to enhance the effectiveness of training

Distance learning through the internet clearly provides major opportunities for the future. Should bodies such as the IAEA not play a more active role in bridging the digital divide by assisting the internet enablement of all regulatory bodies?

There are obvious advantages to the standardization of training and to ensuring a more practical focus in the presentation and examination of training. Should bodies such as the IAEA not facilitate the development of:

(a) Standardized facility (practice) specific training that can be provided through the internet?

(b) Open book exams that could be written via the internet and which focus more on the practical implementation of a regulatory or occupational radiation protection programme?
(c) Peer review or expert missions that evaluate the impact of training on the behaviour of individuals?

6.2. Dosimetry and calibration services

The papers originating from the developing countries generally focus on external dosimetry while the papers from the developed countries tend to focus more on internal dosimetry. This is viewed as part of a natural progression in the implementation of an occupational radiation protection programme. The value of standardization and intercomparisons in dosimetry programmes is again highlighted.

A number of papers indicate that secondary standards dosimetry laboratories have been established in several countries. As a further reflection of the role that the IAEA plays in the development of national infrastructure, two countries mention the IAEA's Regulatory Authority Information System (RAIS).

Discussion points: Management of services

The establishment of a dosimetry and associated calibration service is very important, but requires considerable resources to develop and maintain. In the development of an infrastructure for occupational radiation protection, should the establishment of regional service centres not initially be favoured over national ones?

The provision of standardized databases and methodologies could enhance the effectiveness and efficiency of regulators where they have no choice but to provide certain services. What should be done to promote standardized databases and methodologies aimed at service delivery such as the IAEA's RAIS?

6.3. Radioanalytical services

A number of papers discuss the involvement of the respective regulatory body in the analysis of food that is imported and/or exported. One paper mentions that more than 133 000 samples have been analysed since 1989, but that not a single case of contamination has been found. The value of this effort in a country with developing infrastructure is questionable.

Discussion point: Management of services

In line with the milestones of the IAEA's model project, radioanalytical services (especially for foodstuffs) should only be implemented after an infrastructure to deal with occupational and medical exposures has been implemented fully. What should be done to avoid regulatory resources being diverted to other areas while proper occupational radiation protection has not yet been implemented?

7. GENERAL

From the papers it is clear that developing countries would, in the establishment of their infrastructure, need to spend considerable time on the development of: performance indicators and goals; proposals for fellowships; proposals for training; research agreements with bodies such as the IAEA; project plans for the IAEA and for their own management; maps of regulatory processes; regulations; guides; review checklists; inspections checklists, etc.

Many of these require considerable technical and managerial expertise. Although newly established regulatory bodies in developing countries may have the expertise they may not have the capacity to develop these documents. Furthermore, the effort required to develop these documents would divert the limited capacity of the regulatory body away from the critical implementation of infrastructure, i.e. conducting reviews and inspections. With all the experience gained by developed and model project countries it should be possible to establish standardized facility (practice) specific packages of the above. Although these would still have to be customized to country specific circumstances it is envisaged that such effort would be minimal and would allow personnel to focus on the implementation of infrastructure.

Discussion point: Type and level of guidance for developing countries

Should detailed cradle-to-grave packages of documentation covering all aspects related to the implementation of facility (practice) specific infrastructure not be developed for developing countries so that they could focus more on ‘in-the-field’ implementation, rather than on the ‘in-the-office’ preparation of documentation?

TOPICAL SESSION 2

DISCUSSION

C. SCHANDORF: I suggest that in the discussion we focus first on the issue of the independence of the regulatory body.

A.C. McEWAN: For me, this issue is one of *effective* independence. Every regulatory body is answerable to someone. In order to be effectively independent, it must be able to enforce requirements and must have the financial resources necessary for carrying out a programme that will not be overridden by those interested in the promotion of practices.

D.C.D. URQUHART: I agree with A.C. McEwan. The regulatory body must have effective independence. Also, it must be able to look at safety objectively.

Besides political pressures, however, many of the people working for regulatory bodies have worked previously in the nuclear industry, so there are few ‘pure regulators’. They must, nevertheless, be objective, in order that the public may have confidence in them and in the organizations which they regulate.

R.P. BRADLEY: As regards the interaction between regulatory bodies and regulated organizations, it is in our view important that it be transparent so that the public may see how, and on the basis of what information, decisions are reached. This has been achieved in a number of areas in Canada.

F.I.M. NOLAN: For me, independence means above all that the regulator reports to the national legislature (the parliament) and does so directly, not through a minister; the regulator is then seen to be independent. Admittedly, anti-nuclear groups and similar bodies will continue to question the regulator’s objectivity, but the regulator is likely to be accepted by the general public.

S.B. ELEGBA: In developing countries, and perhaps also in some developed countries, the operating organizations may well precede the regulatory body in time and may well have accumulated substantial resources. In that event, it is important that the regulatory body be provided, under the law establishing it, with adequate funding. Otherwise, it may have to go ‘cap in hand’ for help to the operating organizations which it is supposed to be regulating.

For example, the body regulating the offshore oil drilling industry in a given country may not be able to afford the helicopter needed for flying to the drilling rigs and may, therefore, have to request the use of a helicopter belonging to an operating organization. In such a situation, the regulatory body’s credibility may be undermined.

D.J. BENINSON: In a regulatory body, independence and objectivity are important, but even more important is knowledge about what is to be regulated. Without such knowledge, a regulatory body, regardless of how it has been established, will not take off.

G. GEBEYEHU WOLDE: In my opinion, the regulatory body must not only be independent in taking regulatory decisions but also, and even more importantly, dynamic and able to improve.

O.K. AWAL: In Bangladesh, the Atomic Energy Commission plays a dual role; it promotes and regulates nuclear and radiological practices. Recently, however, the Government decided to establish a separate body responsible for regulation. The people in the Atomic Energy Commission engaged in regulatory activities are unhappy about this decision on the grounds that in a smaller organization they will have less status and credibility. So, perhaps independence of the regulatory body is not as important as, say, the ability to check on compliance with the International Basic Safety Standards.

When talking about independence of the regulatory body, one must bear in mind the culture and resources of the country in question.

A.J. GONZÁLEZ: Unfortunately, 'independence' has often been taken to mean 'administrative independence', sometimes advocated even by experts from developed countries. In some countries, the result has been the creation of 'fictitious' regulatory bodies isolated from reality which engage in 'in-house' work rather than work in the field. Such regulatory bodies established by, say, presidential decree but lacking the necessary knowledge are not going to be respected.

C. SCHANDORF: With a view to making regulatory bodies in developing countries effectively independent, the IAEA is providing fellowship training and the services of experts. In my view, the level of competence in such regulatory bodies depends to a large extent on how they use the assistance which they receive.

J. BILLARD: When talking about radiation protection infrastructure, one should reflect on what may happen if employees are demotivated by changes due to, say, the outsourcing or subcontracting of certain tasks. Demotivated employees are prone to making mistakes that can impair safety. The infrastructure must be robust enough to cope with demotivated employees.

R.H. TAYLOR: I agree. However, if such changes are discussed beforehand honestly and openly with them, rather than being suddenly imposed on them, employees are less likely to be demotivated.

O.K. AWAL: We, as regulators who believe in 'win–win optimization', are trying to increase motivation among employees. We have surveyed all radiation facilities in Bangladesh and determined what their radiation protection shortcomings are, and in the light of our findings we have designed training courses in radiation protection lasting from two days to two weeks with a view to increasing the motivation of employees and their desire to receive long term training. Employees are responding well and the demand for long term training is growing.

V. VENKAT RAJ: Is it possible to quantify adherence to safety culture on the basis of, for example, numbers of procedural violations or near misses?

R.H. TAYLOR: Yes, but much depends on the willingness of workers to report such things as procedural violations and near misses. Workers must feel that, if they report an incident which may well have been their fault, they will be praised for volunteering the information rather than criticized.

In the UK, ‘safety climate surveys’ developed by the Health and Safety Executive are conducted in the nuclear industry and also in other industries. Employees are asked about, for example, compliance with procedures and the challenging of decisions, and over time one is able to detect trends in safety culture. The answers received have to be interpreted with some caution, however, as negative ones may well reflect concerns about things which have nothing to do with safety — pay rates, for example. It is best to analyse the answers in co-operation with the people who gave them.

V. VENKAT RAJ: So it is all rather subjective?

R.H. TAYLOR: Yes, there are no hard numbers to be derived from such an exercise, which relates to perceptions, attitudes and behaviour, not to science and technology.

F.I.M. NOLAN: When talking about ‘safety culture’, we should remember that culture is based very much on language. Scientists speak two languages: the language of everyday life and the language of science. Understanding the language of science requires a grasp of the relationships between numbers, and non-scientists, even if they are intelligent, do not understand it. As a result, scientists are not very successful at communicating with non-scientists about scientific questions.

The motto of our Radiation Safety Institute is “Good science in plain language”. That does not mean that we present science in a simplistic manner. It means that we translate from the language of science into the language of everyday life — a language of simile, metaphor and analogy. That is not easy, but it can be done — to remarkable effect. Ordinary people with whom we have spoken about radiation risks in the language of everyday life are able to take decisions regarding such risks in the same way as they take decisions regarding, say, the kind of mortgage to take out when buying a house.

R.H. TAYLOR: I agree. We scientists must speak to non-scientists about scientific questions in a language which they will understand and we must not be condescending. There is a great deal of room for improvement in this communications area.

P.M. SAJAROFF: In connection with the issue of infrastructure development, I should like to raise the issue of loss of corporate or institutional memory, which can have a direct or indirect impact in the area of occupational radiation protection.

R.H. TAYLOR: Loss of corporate or institutional memory, a serious issue in the UK and in many other countries, can be countered by bringing in, at the bottom of the hierarchy, young people who will gradually replace those who are retiring. In addition, it is necessary to recognize that most of the things which were done in the past were done for good reasons and to discover what those reasons were.

STATUS OF OPERATIONAL IMPLEMENTATION OF BASIC SAFETY STANDARDS

(Topical Session 3)

Chairperson

Z. PROUZA
Czech Republic

IMPLEMENTATION OF THE BASIC SAFETY STANDARDS: SOME THOUGHTS ON PROGRESS AND PROBLEMS

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Abstract

This paper offers comments and observations on international implementation of the International Basic Safety Standards (BSS) and is based on experience and dialogue with professional colleagues. Fifty-one of the 135 IAEA Member States participate in the IAEA Model Project for Upgrading Radiation Protection Infrastructures, including the establishment of occupational exposure control. While this should ensure a high standard of worker protection in all IAEA Member States in due course, it would be desirable for some investigation to be conducted into worker protection conditions in those countries that are not Member States of the IAEA. While the BSS and related guidance documents go a long way towards providing international norms, there are still some areas where a consensus on specific matters is difficult to achieve. One such important issue concerns the scope of application of regulations for occupational radiation protection from natural sources and another concerns the question of what constitutes ‘occupational exposure’. Other implementation issues are: the treatment of pregnant women, uncertainties in dose assessment, the integration with other occupational health and safety measures, and a dose passport for workers. It is also clear that quality management strategies must be consistently applied to systems for occupational radiation protection. Consideration should be given to reviewing and updating, as necessary, the International Labour Organization’s Convention 115 to include reference to the occupational radiation protection requirements of the BSS and to promote regular review and reporting of occupational radiation protection performance by signatory countries.

1. INTRODUCTION

When the author was first asked to prepare a paper concerning the status of operational implementation of the International Basic Safety Standards (BSS) [1], the request was understood to mean reporting on how the countries of the world have put into practice the BSS requirements. Lacking the necessary information, the author realized that such a request could not be satisfied and that it would be virtually impossible to collect such information in a statistically valid way in time for this Conference. Subsequent negotiations with the Conference organizers centred, instead, on providing a personal commentary on implementation issues. What follows then is neither a complete nor thorough account nor a properly conducted survey; rather, it is a personal reflection, based on experience and dialogue with professional colleagues, which attempts to draw attention to some of the more salient implementation issues.

2. STATUS OF IMPLEMENTATION OF BSS REQUIREMENTS

There are 135 Member States of the IAEA. Of these, several were identified by the IAEA in 1995 as being, in some way, in need of support and assistance in developing their radiation protection practices so as to meet the requirements of the BSS, and 51 became participants in a Model Project for Upgrading Radiation Protection Infrastructure (‘model project’) [2]. There are a similar number of countries that are not Member States of the IAEA. Milestone 2 of the model project concerns the establishment of occupational exposure control by national regulatory frameworks, and requires, inter alia, individual and workplace monitoring programmes to be in place and proper dose assessment and record keeping.

IAEA Member States not involved in the model project are generally fully developed countries with a history of good regulatory control of occupational exposure. Member States of the European Union, for example, must comply with a European Directive [3] that sets requirements essentially consistent with those of the BSS. Model project countries are progressively implementing their regulatory frameworks, some being further advanced than others in completing the project milestones. Little is known about the standard of radiation protection in countries that are not IAEA Member States. Using the various goals under milestone 2 as a reference, the status of international implementation of measures equivalent to the BSS requirements for occupational radiation protection are summarized in Table I.

While the countries in the left hand column of Table I are typically those that make most use of radiation sources, including countries with nuclear industries, the overall picture falls well short of what is desirable. The situation is further complicated by the concern that economic constraints in some countries are having a negative impact on regulatory effectiveness and safety standards and also by the lack of clarity concerning regulatory control of exposures from naturally occurring sources (see below).

Comment: Continuing efforts exercised through the model project combined with the possibility of internationally binding reporting and review requirements being satisfied in the future should ensure a high standard of worker protection in all IAEA Member States in due course, but it would be desirable for some investigation to be conducted into worker protection conditions in those countries that are not Member States of the IAEA. Although it is not clear how such a study or any subsequent assistance could be funded, the current climate for promotion of source security measures around the world may assist in this regard. A joint approach by the international organizations could capture most countries.

TABLE I. DEGREE OF COMPLIANCE WITH BSS REQUIREMENTS[a]

IAEA Member States not involved in the model project	IAEA Member States participating in the model project	Countries that are not IAEA Member States
Almost 100%	50–80%	unknown[b]

[a] Taken here to be those requirements identified under milestone 2 of the model project [4].
[b] Unknown to the author.

3. SOME ISSUES OF IMPLEMENTATION OF BSS REQUIREMENTS

While the publication of the BSS, with the participation of more than fifty countries and eleven international or regional organizations in its drafting, reflects a remarkable consensus achievement, there remain some areas requiring further clarification or new guidance. Some of these are discussed further here. The problems often arise because general philosophy and policy expressed in publications of the International Commission on Radiological Protection (ICRP) need to be cast in a definitive and quantitative form for the purposes of regulation. While the BSS and related guidance documents go a long way towards providing international regulatory norms, there are still some areas where a consensus on specific measures is difficult to achieve.

3.1. Natural sources and the scope of application

There continues to be some debate about which industries should fall within a regulatory regime for control of occupational exposure. The problem occurs principally in those industries that are involved in mining or processing materials that contain naturally occurring radionuclides. At one end of a spectrum there is universal agreement that the mining of uranium should be considered a practice and subject to regulatory control, but for other raw materials, as the radionuclide content decreases so the degree of control needed becomes less. Approaching the spectrum from the other end, the concept of intervention is applied to the circumstances of exposure, but for some industries where intervention does not sufficiently reduce exposure, the requirements for practices may need to be invoked. Unfortunately, as practices and interventions are disjoint concepts, there is no clear and simple transition from one to the other.

While the IAEA, the ICRP, the OECD Nuclear Energy Agency and others have all been giving attention to the issue of scope of application of radiation controls generally, for the particular case of occupational exposure which includes exposure to natural sources there seems to be sufficient general guidance, for example, as set out in the IAEA Safety Guide on Occupational Radiation Protection (RS-G-1.1) [5]. The guidance can be summarized as follows:

(a) Where exposure is directly related to the work (such as mining of radioactive ores), the exposure should be subject to the requirements for practices.
(b) Where exposure is incidental to the work (such as exposure from radon in non-mining workplaces), it should be compared with a predefined action level:
  (i) Where the exposure falls below the action level, it is excluded from the requirements.
  (ii) Where the exposure exceeds the action level, remedial action should be taken. If, subsequently, exposure remains above the action level, the requirements for practices should be applied.

Further guidance on mining and mineral processing activities will be provided in a future IAEA publication on occupational radiation protection in the mining and processing of raw materials. It is suggested that raw materials be divided into four categories that are distinguished by the type of activity and circumstances of exposure:

(1) Uranium and thorium ores, i.e. ores that are mined for their uranium or thorium content.
(2) Other raw materials containing elevated levels of natural radionuclides (e.g. mineral sands, phosphatic materials), or materials in which the activity concentration of natural radionuclides has been increased during processing (e.g. deposits or scales sometimes generated in the processing of ores), for which measures for occupational radiation protection are required to protect against exposures to external gamma radiation, dust and/or radon.
(3) Raw materials that do not contain elevated levels of natural radionuclides but for which measure for occupational radiation protection are required to protect against exposures to radon arising adventitiously in the workplace environment; examples include underground mines where radon levels are high.
(4) Other raw materials.

The first of the above categories is a practice and requires a licence, while the last requires no authorization. The degree of control in the other two cases should be matched to the level of hazard. The second category is considered a practice, as defined in the BSS, and a licence is needed, but the stringency of requirements would be expected to diminish industry by industry as the circumstances of exposure lead to smaller occupational doses. The third category applies to natural exposures in workplaces generally, where exposures are excluded unless they exceed the predefined action level. Safety Guide RS-G-1.1 also provides guidance on action levels.

For radon in the workplace, the action level is 1000 Bq/m^3; for bulk ores and minerals the action level would be set in the range 1–10 Bq/g of the parent nuclide [5].

The European Commission has provided similar guidance for implementing the European Directive in the case of naturally occurring radionuclides, but with categories or bands delineated by dose [6]. For example, effective doses above 1 mSv/a in normal operation require a 'lower level' of regulation, while doses above 6 mSv/a require a 'higher level' of regulation. Using dose as the only criterion should be viewed with caution, however, as the essential element of excluding exposures that are unamenable to control may be lost through inappropriate application. For example, there may be a tendency to treat the figure of 1 mSv/a as having a more broadly applicable defining function than intended and to regard any exposures at work above that value as occupational exposure and requiring regulation, regardless of the circumstances. This would be too crude a distinction and would lead to inconsistencies, for example with the approach for radon.

Comment: While the general approach to defining regulatory scope for occupational radiation protection is close to achieving a consensus, it would be of great help to industry if regulatory authorities were to follow through and specifically identify those activities that should be regulated and what degree of control would be applied. If guidance could be developed at the international level, so much the better.

3.2. What constitutes occupational exposure?

Traditionally, the International Labour Organization (ILO) has regarded all exposure received at work as occupational exposure. While this is a perfectly valid way to define occupational exposure, it means that it then becomes necessary to also define the component of occupational exposure that should be subject to regulatory control. Clearly, the component of radiation exposure received from handling artificially made radioactive sources at work is occupational exposure, but a worker's total exposure also includes natural background exposure during working hours. This latter component can usually be regarded as simply a natural consequence of living on the surface of the earth and not related to the nature of the work. It might differ in type and magnitude from the exposure that would have been received had the person not been at work, but could not be regarded as being caused by the work or being the responsibility of the employer to control. However, some workplaces have higher levels of natural exposure than others and there are a few where the exposures are so high that there is general agreement that action should be taken to reduce the dose. Where should the line be drawn between what is merely a natural part of living and what should be subject to control?

To draw the distinction, the ICRP [7,8] uses the phrase "exposures incurred at work as the result of situations that can reasonably be regarded as being the responsibility of the operating management". The BSS goes further in specifying where regulation should commence by defining occupational exposure as "All exposures of workers incurred in the course of their work, with the exception of exposures excluded from the Standards and exposures from practices or sources exempted by the Standards." Exposures that are unamenable to control (such as radon at low levels, or cosmic radiation at the earth's surface) are excluded. It would seem desirable to align the definition of occupational exposure for regulatory purposes with the guidance described in Section 3.1, that is, where the requirements for practices are applied to exposure received at work, it is occupational exposure.

3.3. Some other implementation issues

Some other implementation issues need to be considered, including the following:

(a) *Treatment of pregnant workers.* The BSS require that a worker who has notified a pregnancy shall be provided with alternative working conditions, if necessary, to ensure that the embryo or fetus is afforded the same broad level of protection as that given to members of the public. This sensible but imprecise requirement is difficult to cast in regulatory form. The ICRP has amended its earlier advice to recommend that the working conditions should be modified to make it unlikely that the equivalent dose to the embryo or fetus will exceed 1 mSv [8]. This more specific requirement is helpful, but certain exposure scenarios, for example when exposure arises from the intake of radionuclides, may require further evaluation [9].

(b) *Uncertainties in dose assessment.* While not attracting a great deal of attention at present, concerns have been raised in the past about the scientific uncertainty inherent in any estimate of individual dose, including both the modelling, if any, used to estimate dose from raw data, and the measurements themselves. What is clear is that uncertainties in dose estimation can be high and often amount to a factor of two or more. The consequent concerns extend to the possible ramifications should such an estimate be used in legal proceedings, for example, in the prosecution of an employer for failure to comply with the dose limits. It could be difficult to prove to the satisfaction of a court that a dose limit had been exceeded unless the estimated dose was very much greater than the limit. There would seem to be a need for further guidance.

(c) *Integration with other occupational health and safety measures.* Although the BSS make reference to non-radiological occupational health and safety requirements, there is little guidance on how to achieve overall coherence of safety measures in the workplace. The practices and language of radiation protection have developed separately from other occupational health and safety traditions, although it is not difficult to show an essential consistency between them. It is important, however, that occupational health and safety in the workplace be managed coherently across the spectrum of workplace hazards. There is room for some practical guidance on this matter.

(d) *A dose passport for workers.* The Russian Federation has some experience of using ‘passports’ containing health information to allow workers to move from job to job while ensuring proper tracking of their total radiation exposure, and other countries have used passbooks in certain circumstances. A proposal has been made at this Conference to introduce a similar scheme across Europe and more widely [10]. There is certainly some merit in the idea, at least in providing employees with a regularly updated personal history of their exposure, in order to ensure continuity of appropriate protection.

4. CONCLUDING POINTS FOR CONSIDERATION

Despite there being room for further elaboration of the BSS requirements in some areas, the principal implementation issue likely to give rise to harm to workers is the failure of regulatory and workplace systems to implement the requirements. Concerns have been expressed about the effect of long term economic difficulties on the effectiveness of controls and about the ageing of the technically experienced workforce, in nuclear science in particular, and the shortage of people seeking careers in related disciplines. There are further concerns that the nature of working in radiation environments is changing, for example, as more nuclear facilities reach the decommissioning stage, and that this could lead to practices that cause an increase in exposures. It is clear that quality management strategies must be consistently applied to systems for occupational radiation protection to ensure that workers are duly protected at all times. Consideration could be given to reviewing and updating, as necessary, ILO Convention 115 to include reference to the occupational radiation protection requirements of the BSS and to promote regular review and reporting of occupational radiation protection performance by signatory countries.

There is one BSS provision that seems to have been little used, if at all — the provision for ‘special circumstances’ in setting dose limits. The need for the provision arose during the drafting of the BSS from the submissions made by the uranium mining industry and parts of the medical community, which were concerned that strict adherence to an annual dose limit of 20 mSv might have an adverse impact on specific justified practices. In the light of seven years experience with the BSS and the lack of enthusiasm among regulatory authorities to make use of the provision, the time may have come to discard it. Consideration should be given to removing the special circumstances dose limit provision from any revision of the BSS.

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THE IAEA TECHNICAL CO-OPERATION MODEL PROJECT ON UPGRADING RADIATION PROTECTION INFRASTRUCTURE: A PROACTIVE APPROACH FOR IMPROVING SAFETY

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Abstract

An unprecedented international co-operative effort has been launched to improve radiation and waste safety infrastructure in more than fifty IAEA Member States within the framework of the IAEA's Technical Co-operation Model Project on Upgrading Radiation Protection Infrastructure. The objectives of the project are to establish an adequate radiation and waste safety infrastructure, compatible with the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources, in those Member States receiving IAEA assistance, including a system of notification, authorization and control of radiation sources, and an inventory of radiation sources and installations. These objectives are in line with the statutory mandate of the IAEA, which provides that safety standards are also to be applied to its own operations, including all technical co-operation activities. The paper describes the IAEA's proactive approach used to design, implement and assess the project. By the end of September 2001, about 77% of the participating countries had their laws promulgated and regulatory authorities established; more than 42% had their regulations adopted; about 50% had a system for the notification, authorization and control of radiation sources in place and operational; and about 80% had an inventory system of radiation sources and installations in place and operational.

1. BACKGROUND

By its Statute, the IAEA is authorized to establish or adopt safety standards for protection of health and minimization of danger to life and property, and to provide for the application of these standards to its own operations as well as to operations making use of materials, services, equipment, facilities and information made available by the IAEA. One of the main components through which these standards are applied is the IAEA's Technical Co-operation (TC) programme.

Since 1984, information specifically relevant to radiation safety infrastructure was obtained through more than sixty expert team missions undertaken by Radiation Protection Advisory Teams, follow-up technical visits and hundreds of individual expert missions undertaken within the framework of national, regional and/or interregional TC projects. Building on this experience and subsequent policy reviews, the

IAEA took steps to evaluate more systematically the need for technical assistance in the areas of nuclear and radiation safety. The outcome was the development of an integrated strategy designed to assess needs and priorities more closely and to optimize resources for upgrading radiation and waste safety infrastructures in IAEA Member States receiving its assistance. The main components of this strategy consist of collecting and evaluating information on the existing safety infrastructure, establishing and maintaining Country Radiation and Waste Safety Profiles and formulating and implementing Country Radiation and Waste Safety Action Plans. The latter are needed to rectify safety gaps and to sustain an effective radiation and waste safety infrastructure.

To implement the above strategy, the IAEA in 1994 included in its TC programme a Model Project on Upgrading Radiation Protection Infrastructure (‘model project’) in Member States receiving its assistance.

2. PROJECT OBJECTIVES AND MAGNITUDE

The objectives of the model project are to assist those IAEA Member States which have an inadequate radiation protection infrastructure and which are receiving IAEA assistance to comply with the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS).

It was originally envisaged, in 1994, that some five or six Member States would benefit each year from the model project. However, material gathered indicated that more than fifty countries were in need of assistance. Hence, programme and management adjustments had to be made. An integrated management approach was thus developed with the aim of providing adequate national radiation and waste safety infrastructures in the participating countries. In support of this approach, the IAEA currently has five ‘regional project managers’ appointed for Africa, East Asia, Europe, Latin America and West Asia.

3. COUNTRY RADIATION AND WASTE SAFETY PROFILES

Draft country radiation and waste safety profiles were prepared for all the participating countries. The reason for the establishment of these profiles is to keep updated all the data known to the IAEA on the radiation and waste safety infrastructures of the country concerned. Files containing information on laws and regulations, as well as mission reports, papers describing the situation, and other material and relevant safety action plans. The essential structure of the system relies on a questionnaire, the answers to which provide the basic inputs for the computerized database.

The questionnaire and derived database cover the following main sections: organizational infrastructure; legal and regulatory status; training; extent of practices; individual monitoring; public exposure control; medical exposure control; radioactive waste safety; transport of radioactive material; planning for, and response to, radiation emergencies; and quality assurance.

4. COUNTRY RADIATION AND WASTE SAFETY ACTION PLANS

For all the participating Member States, Country Radiation and Waste Safety Action Plans were developed from an analysis of the above-mentioned profiles with regard to the requirements for an adequate safety infrastructure, in accordance with the BSS. The action plans cover five milestones:

Milestone 1: The establishment of a legislative and regulatory framework

Milestone 1 constitutes the most time consuming activity, involving the drafting, approval and/or promulgation of radiation and waste safety legislation and regulations; the creation and empowerment of a national regulatory authority; the establishment of a working system of notification, authorization and control of radiation sources together with the establishment of an inventory of radiation sources and installations.

Milestone 2: The establishment of occupational exposure control

The establishment of occupational exposure control includes, inter alia, individual and workplace monitoring, dose assessment, quality management, etc.

Milestone 3: The establishment of medical exposure control

The establishment of medical exposure control is aimed at controlling the exposure of patients in diagnostic radiology, radiotherapy and nuclear medicine, and includes establishment of an appropriate quality assurance programme.

Milestone 4: The establishment of public exposure control

The establishment of public exposure control covers protection of the public and the environment. It includes programmes for the registration, control and safe disposal of radioactive waste, the control of consumer products containing radioactive substances, and environmental monitoring.

Milestone 5: The establishment of emergency preparedness and response capabilities

The establishment of emergency preparedness and response capabilities involves the development of plans and the allocation of the means to ensure the effectiveness of the national regulatory authority and other relevant organizations in dealing with different radiological emergency scenarios.

The implementation of milestones 2, 3, 4 and 5 is strongly dependent on the effective establishment of the first milestone.

The action plans include tasks and actions which are the responsibility of the Member State, and tasks which are the responsibility of the IAEA and which have an agreed timetable. The action plans cover both generic and specific activities. Generic activities apply to all countries and as a first priority cover notification, authorization and control of all radiation sources together with an inventory of radiation sources — whatever their use — within the country. Specific activities are tailored to each country's particular needs, such as staff training or the provision of necessary equipment.

The development of human resources through training is an important component of the model project. It involves not only training in nuclear technologies but also provides instruction to administrators, regulators, radiation protection specialists and medical personnel. The establishment and sustainability of a sound infrastructure for ensuring radiation and waste safety depends heavily upon national capabilities in these areas.

5. COMMITMENT BY GOVERNMENTS

The model project presumes that governments and national authorities are prepared to comply with their obligations as described in the Preamble to the BSS. For this reason, firm commitments were obtained from all participating countries, while all country action plans were discussed and finalized, and then approved by relevant counterparts and authorities in each participating Member State. The implementation of the country radiation and waste safety action plans could not start before obtaining official approval from the Member State concerned. As a result of this approach, Member States firmly committed themselves to establishing a national infrastructure, which includes, inter alia:

(a) Appropriate national legislation and/or regulations (the type of regulatory system will depend on the size, complexity and safety implications of the regulated practices and sources as well as on the regulatory traditions in the country);
(b) A regulatory authority empowered and authorized to inspect radiation users and to enforce the legislation and/or regulations;

(c) Sufficient resources and technical services;
(d) Adequate numbers of trained staff.

6. STANDARDIZATION AND HARMONIZATION OF ACTIVITIES

The efficient use of resources implies a balance between standardized measures and respect for the circumstances of each specific Member State. A number of activities and tasks have been harmonized, thus improving the level of common understanding of all concerned. These are described in the following paragraphs.

A document that is instrumental in the implementation of the first milestone of the model project is the technical document entitled Organization and Implementation of a National Infrastructure Governing Protection against Ionizing Radiation and the Safety of Radiation Sources. This document provides guidance on how to optimize and integrate each element of a regulatory infrastructure with the remaining elements. The elements covered include regulations, authorization, exemption, inspection, enforcement, accident investigation and dissemination of information. A model legislation to establish a regulatory authority (as presumed in the BSS), model regulations based upon the BSS and model regulations covering radioactive waste management safety and radioactive transport safety have all been developed. All model legislation and regulations were translated into Arabic, French, Russian and Spanish.

Once the system of notification, authorization and control of radiation sources has been designed, there is a need for advice on how to implement it. A technical document was prepared describing methods and review plans to facilitate authorization and inspection of radiation sources, including how to prepare and conduct an inspection and follow-up actions. The document includes specific checklists for the main practices (such as industrial radiography, use of industrial irradiators, gauging, radiotherapy, nuclear medicine, diagnostic radiology, among others) in order to assist regulatory authorities in reviewing safety in the processes of authorization and inspection.

The management of the regulatory programme needs prompt and updated information for planning, optimizing resources, monitoring safety related data, disseminating safety information, making decisions and following up regulatory actions, including monitoring deadlines. For this purpose, a software package known as the Regulatory Authority Information System (RAIS) has been developed and is currently being used by most participating Member States. The software comprises five modules, covering: inventory of radiation sources and installations; authorization process; inspection and enforcement; dosimetry of occupationally exposed personnel; and performance indicators for individual installations as well as for the overall regulatory programme.

Training of personnel for regulatory authorities and radiation users has been provided in a synchronized and standardized manner through regional and national training courses and workshops. Syllabuses, prospectuses and training manuals were standardized and translated into Arabic, French, Russian and Spanish.

7. PEER REVIEW

As the organization/implementation of the country safety action plans progresses, both the Member States and the IAEA need to assess the effectiveness of the measures taken at the different stages in order to correct weaknesses and optimize resources. For this purpose, an IAEA publication was recently produced[1] and is currently being reviewed. The document provides advice on the conduct of peer reviews using a methodology to obtain qualitative and quantitative information and on its analysis with respect to performance criteria and indicators. Qualitative information (e.g. the quality of a safety assessment for licensing and inspection purposes) is being analysed by peer reviews conducted by senior experts and is greatly facilitated by the readily available and reliable information on the regulatory programme available in the RAIS.

The peer review missions were implemented during 1999–2001. Thirty-two Member States participating in the model project were visited between August 1999 and September 2001. The terms of reference of each peer review were to:

(a) Determine the status of radiation safety and assess the national regulatory infrastructure, in particular with respect to its establishment, organization and implementation;
(b) Determine how effective the model project has been in improving the situation in the country;
(c) Submit findings, conclusions and recommendations, if any, for further strengthening of the national infrastructure for radiation protection and safety.

8. PROGRESS ACHIEVED

During implementation, project activities were continuously monitored, inter alia, through regular co-ordination and planning meetings with participating Member

[1] INTERNATIONAL ATOMIC ENERGY AGENCY, Assessment by Peer Review of the Effectiveness of a Regulatory Programme for Radiation Safety, IAEA-TECDOC-1217, Vienna (2001).

States in each of the five regions. The meetings provided opportunities for establishing direct contact with persons having political responsibilities (ministers, deputy ministers, members of parliament, etc.) and executive responsibilities (chairpersons of atomic energy commissions, directors of regulatory authorities, project counterparts, etc.) in their countries with a view to facilitating the implementation of the project.

As a result of the above monitoring activities and the peer review missions, the status of project implementation as of September 2001 can be summarized. As regards milestone 1, activities were implemented with varying degrees of success by the participating countries to the extent that:

(a) About 77% had promulgated laws;
(b) About 77% had established a regulatory authority;
(c) More than 42% had adopted regulations;
(d) About 80% had an inventory system in place and operational;
(e) About 50% had a system for the notification, authorization and control of radiation sources in place and operational.

From the above figures, it may be concluded that about 50% had achieved the regulatory level of compliance presumed in the Preamble to the BSS by completing all activities foreseen under milestone 1. Considering the nearly six years of implementation, this specific level of achievement is much lower than originally expected; the time necessary to overcome some of the difficulties (already identified at the time of project design) was underestimated. Many countries did not attain milestone 1 for one or all of the following reasons:

(a) Time consuming legislative and regulatory procedures and institutional instability;
(b) Budgetary constraints, resulting among other things in high turnover of qualified staff;
(c) Unfocused regulatory structures (overlapping responsibilities);
(d) Limited regulatory independence and empowerment;
(e) Inadequate supplementary documentation (implementing regulations, authorization and inspection procedures, and regulatory guides);
(f) Insufficient financial and technical resources, trained staff and support services (e.g. individual monitoring).

Where possible, some activities relating to other milestones, particularly milestone 2, were initiated in parallel with the implementation of activities for attaining milestone 1. Progress made towards attaining milestones 2–5 by the end of September 2001 can be summarized as follows:

(a) Programmes for occupational exposure control (milestone 2) were being successfully implemented in most countries, with about 79% having individual monitoring and about 56% having workplace monitoring established and operational.

(b) Substantial parts of activities relating to milestones 3–5 had yet to be implemented by most of the participating countries.

9. CURRENT ACTIVITIES

By the end of September 2001, the Secretariat had received requests from the following 29 countries (additional to the 52 Member States which participated in the first phase of the model project): in Africa — Angola, Burkina Faso, Egypt, Kenya, the Libyan Arab Jamahiriya, Morocco, Tunisia and the United Republic of Tanzania; in East Asia — China, Indonesia, Malaysia, Pakistan, the Philippines, Singapore and Thailand; in Europe — Bulgaria, Croatia, Hungary, Malta, Portugal, Romania, Slovenia and Turkey; in Latin America — Ecuador, Haiti, Uruguay and Venezuela; in West Asia — the Islamic Republic of Iran and Kuwait.

10. CONCLUSIONS

From the aforementioned continuous project monitoring and the peer reviews, it may be concluded that substantial progress has been made in upgrading the radiation protection infrastructures in participating countries, especially the regulatory framework, including the systems for the notification, authorization and control of radiation sources and for occupational exposure control.

With respect to the results achieved, the participating countries may be divided into three categories:

(1) Countries advanced in project implementation, which have attained milestones 1 and 2 and which have succeeded in implementing several activities related to other milestones.

(2) Countries where there have been some implementation delays due to budgetary and/or organizational constraints; these countries need to revise existing legislation and restructure existing radiation protection systems. There are indications that the national authorities concerned have become more committed and that steps have been taken to expedite project implementation. If the observed trends continue, and there are no serious further delays, these countries should be able to report substantial progress in meeting the principal requirements of the BSS in the foreseeable future.

(3) Countries where there have been major implementation delays as a result of difficulties due to institutional instability; severe, general infrastructural weaknesses; inadequate support at the decision making level; changes in national programme priorities; inability to recognize the magnitude of certain problems; and failure to mobilize the necessary national human and financial resources. These countries had not even attained milestone 1. Further project monitoring and peer review missions in these countries are considered by the Secretariat to be necessary in order to assess progress, make recommendations and optimize the assistance effort for future improvements.

RAPPORTEUR SUMMARY

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1. INTRODUCTION

In Topical Session 3, the contents of the nine papers presented can be grouped, from a thematic perspective, into five main areas:

(1) 'As low as reasonably achievable' (ALARA) network management [1],
(2) Radiation protection of the female worker and her offspring [2],
(3) Worker passports [3, 4],
(4) Upgrading of occupational radiation protection regulations [4–8],
(5) Personal dosimetry [9].

The objective is to stimulate discussion through the identification of common issues or areas of disagreement.

2. ALARA NETWORK MANAGEMENT

Since 1996, the European ALARA Network [1] has promoted and disseminated at regional level the application of optimization techniques in a number of practices. The obvious goal is the use of this tool for improving occupational radiation protection. The issues for discussion are as follows:

(a) Should similar networks be implemented in other regions at multilateral level (e.g. in Latin America, Eastern Europe, Africa and West Asia)? Should mutual interaction among them and the feedback of operating experience also be promoted?
(b) ALARA seems to be adequately implemented over a wide range of predictable working scenarios. However, it is still a matter of concern in some cases connected with:
    (i) The protection of female workers and the children yet to be born in some intake specific scenarios [2],
    (ii) Management of internal exposure [5],
    (iii) Personal dosimetry in one case of diagnostic radiology service [9].

(c) Further areas/operations in which ALARA needs strengthening:
   (i) Research reactors,
   (ii) Fuel cycle installations other than reactors,
   (iii) Industrial radiography (particularly gamma radiography),
   (iv) Radiodiagnostics and radiotherapy,
   (v) Research activities,
   (vi) Non-nuclear industries (naturally occurring radioactive material and technologically enhanced naturally occurring radioactive material) [4].

3. RADIATION PROTECTION OF THE FEMALE WORKER AND HER OFFSPRING

The goal is to achieve and maintain an adequate level of protection. The ad hoc paper [2] deals mainly with specific inhalation scenarios in normal working conditions and accidental scenarios.

The issue for discussion is whether the International Commission on Radiological Protection's (ICRP) Publication 88 should be expanded in order to also include:

(a) Additional normal working conditions (continuous intake of specific radionuclides in the year before pregnancy[1] and, similarly, over 5 years before pregnancy[2]);
(b) Further accidental situations involving additional radionuclides (acute intake at conception or in early pregnancy[3], and inhalation at 0.5 and 2.5 years before pregnancy[4]);
(c) Dose coefficients for some radionuclides for embryo and fetus vis-à-vis continuous intake during the first weeks of pregnancy.

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[1] Nuclides ^{55}Fe, ^{65}Zn, ^{79}Sn, ^{59}Ni, ^{63}Ni (when the intake by the mother lies close to the annual limit, the dose to the offspring may exceed 5 mSv).

[2] Nuclides $^{108}Ag^{m}$, ^{125}Sb, ^{210}Pb, ^{59}Ni, ^{63}Ni (the effective dose to the offspring could be higher than 5 mSv and up to 55 mSv respectively).

[3] Nuclides ^{3}H, ^{14}C, ^{35}S, ^{75}Se, ^{89}Sr (the effective dose to the offspring would be higher than the dose to the mother, and up to six times the dose to the mother in the last case).

[4] Nuclide ^{63}Ni (the dose to the child to be born could be 75% and 50% higher than the dose to the mother respectively).

4. WORKER PASSPORTS

A European worker passport is proposed for dosimetric and medical follow-up of workers when they perform their tasks in various nuclear power plants located at regional level [3].

The system of radiologically hygienic passports was implemented in 89 regions of the Russian Federation to obtain information useful to regulatory and managerial decision making [4].

The issues for discussion are:

(a) The contribution made by these passports to the improvement of occupational radiation protection.
(b) Whether they should also deal with non-radiological risks.
(c) Interfaces, at the European level, between European worker passports and national and ISPRA passbooks. How will the databases of all these documents share and exchange dosimetric information on each mobile worker at each nuclear power plant?

5. UPGRADING OF OCCUPATIONAL RADIATION PROTECTION REGULATIONS

Five papers [4–8] deal with this subject, their common objective being coherence with ICRP recommendations and with the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources.

The issues for discussion are:

(a) Difficulties found:
  (i) The interpretation of routine individual monitoring of ^{54}Mn in lungs; the model of removal/retention given in ICRP Publication 30 is not applicable and some of its aerosol compounds are not considered in this publication.
  (ii) How to decrease uncertainties when considering intake conditions, type of chemical compound, aerosol size distributions, etc.
  (iii) The distribution of individual doses; the log normal most frequent distribution given by the United Nations Scientific Committee on the Effects of Atomic Radiation was not valid in one case and, therefore, the development of a new statistical distribution tool was necessary.
  (iv) Regarding neutron exposure monitoring, taking into account that the weighting factors used in the International Basic Safety Standards and those used in ICRP Publication 26 differ cardinally, a new method for the

assessment of equivalent dose due to intermediate and fast neutrons was elaborated.

(v) Adoption of occupational radiation protection standards for the use of mineral materials in non-nuclear industries.

(b) Organizational/infrastructure improvement and building technical competence at all levels (employer, worker and regulator) as contributions to reducing occupational exposure.

(c) Occupational radiation protection in non-nuclear industries.

(d) The role of the radiation safety regulatory authority.

6. PERSONAL DOSIMETRY

In one case it was verified that most diagnostic radiology workers don't use personal dosimeters as required by law [9]. Working conditions are the key to determining the need for the use of personal dosimetry.

The issues for discussion are:

(a) The need to build competence at all levels: employer, worker, regulator and, also in this case, the legislator.

(b) Legal prescriptive requirements or performance based regulations?

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TOPICAL SESSION 3

DISCUSSION

S.B. ELEGBA: Nigeria has benefited from the IAEA's RAPAT services and is now benefiting from the IAEA's Model Project for Upgrading Radiation Protection Infrastructure in Africa, and from my experience I would say that the evolution from the RAPAT service to the model project has been very significant.

Under the model project, the IAEA demanded in 1995 that Nigeria introduce legislation regulating the use of ionizing radiation. A draft law had been in existence for about 14 years without being adopted; two months after the IAEA's demand it was adopted. In 1999, the IAEA demanded that Nigeria introduce regulations for implementation of the law; they were promulgated within two weeks. The IAEA's proactive approach worked.

As I indicated in Topical Session 2, however, when the government of a developing country passes radiation protection legislation, it may well say to the regulatory body "We are ready to pay your salaries and part of your running costs, but you must find the money necessary for covering the rest of your running costs yourselves." The problem there is that, unlike the operating organizations which it is supposed to regulate, the regulatory body does not generate any income.

S. VAN DER WOUDE: I have participated in peer review missions in connection with that model project and I think that the various project milestones constitute quite a good logical framework for it. However, there is a tendency for people participating in the model project to undertake actions such as switching from the use of film badges to TLD or analysing large numbers of food samples when the actions are not necessary. That is a waste of resources and the IAEA should encourage the peer reviewers to point it out.

A. MASTAUSKAS: I suggest that in countries where the model projects for upgrading radiation protection infrastructure in various regions are being implemented, the IAEA organize meetings between, on the one hand, the radiation protection professionals, including members of the regulatory body, and on the other, parliamentarians and governmental officials in order that the latter may gain a better understanding of what is needed for infrastructure development.

G. GEBEYEHU WOLDE: My experience of the past four years suggests that the institutions participating in the model project for upgrading protection infrastructure in Africa have benefited greatly from it. The system of milestones makes for clarity and the regional approach to countries with similar needs and conditions makes for high cost effectiveness.

K. MRABIT: I like to feel that, together with participating countries, we have achieved good results within a very short time through the model projects for improving radiation protection infrastructure in various regions. Of course, there is always room for improvement. Even with the best legislation, the best regulations and the best equipment, a country will not get far without people who are properly educated and trained in radiation protection.

Besides the education and training component of the action plan for each country participating in the model projects, the IAEA provides education and training in radiation protection more generally, as part of a strategy designed to achieve sustainability in education and training relating to radiation and waste safety by 2010. Pursuant to that strategy, the IAEA has designed over 20 training packages which are being used in developed as well as developing countries to train the trainers.

Also pursuant to that strategy, the IAEA is promoting distance learning. Moreover, the paper based modules for distance learning are being converted into electronic form for interactive ‘e-learning’, through which we hope to help more people, including more people living in remote areas.

As S. van der Woude said, there is some waste of resources. We hope to do something about that through the recently established Occupational Radiation Protection Appraisal Service, which, in common with the strategy I just referred to, will complement the model projects.

W. BINES: Regarding paper IAEA-CN-91/122, I should like to know how the proposed European Worker Passport for contract workers will differ from documents such as the UK’s Radiation Passbook for outside workers?

Also in the paper there is mention of “the confidentiality of dosimetric data which cannot be communicated to the employer” in the case of France. I believe that the confidentiality of such data vis-à-vis the employer could be a problem in some other European countries as well, although not in the UK, where we believe that the employer should have the employee’s dosimetric data in order to be able to ensure that doses are being kept as low as reasonably achievable.

Z. PROUZA: I understand that the proposed European Worker Passport will not replace national documents containing dosimetric data.

W. BINES: Will the European Worker Passport have to be carried also by contract workers in the medical sector?

Z. PROUZA: In the Czech Republic it will.

K. SCHNUER: It will have to be carried by all Category A contract workers, regardless of where they are working, so they will have to carry one when working at a place where ionizing radiation is being used in medicine.

Council Directive 90/641/Euratom of 4 December 1990 on the operational protection of outside workers exposed to the risk of ionizing radiation during their activities in controlled areas foresaw that a Europe-wide network for the radiological protection of outside workers would be only a temporary measure for tracking contract workers. The EU Member States have more or less decided that it will be difficult to establish such a Europe-wide network and that the European Worker Passport is the best way of controlling the doses of contract workers.

As regards confidentiality, the Directive requires that workers have access to their own dose data, so confidentiality considerations should not be an argument against the European Worker Passport. Moreover, if the effective dose is not the regulatory dose, the Directive offers the option of introducing the operational dose, information about which is provided to the employee when he/she changes his/her place of work.

A.J. GONZÁLEZ: This is an area where there are major differences between, on the one hand, European requirements and, on the other, the International Basic Safety Standards.

Firstly, in the International Basic Safety Standards there is no categorization of workers, only of places of work.

Secondly, the International Basic Safety Standards do not recommend the issuing of radiation passports. One reason for this is that they assign responsibility for occupational radiation protection, and hence for keeping employee dose records, to employers, and the issuing of radiation passports might enable employers to wash their hands of that responsibility. A further, and more important, reason is a technical one. Before the International Basic Safety Standards were adopted, occupational doses were controlled with the help of a formula which included worker age as a parameter. A radiation passport was very important at that time, since there was a need to have a record of earlier doses so as to know whether one was complying with the formula. The International Basic Safety Standards, however, control the committed dose due to a particular activity, the dose history of the worker is not relevant.

Thus, the European Worker Passport will be a bureaucratic instrument meeting the wish of employers to wash their hands of their responsibility.

Z. PROUZA: In my opinion, until there is a European registry of occupational exposures, the European Worker Passport will be more than just a bureaucratic instrument; it will facilitate the movement of contract workers between European countries and will be useful not only to licensees but also to regulatory bodies.

P.M. SAJAROFF: In my presentation, I was rather diplomatic when commenting on the idea of the European Worker Passport. In my opinion, working conditions are what is important, not the category assigned to a worker.

As suggested by A.J. González, in the early 1970s a radiation passport might have been a reasonable way of improving occupational radiation protection, but not now.

MONITORING OF OCCUPATIONAL RADIATION EXPOSURES

(Topical Session 4)

Chairperson

K. FUJIMOTO
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MONITORING OF OCCUPATIONAL RADIATION EXPOSURES

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Abstract

The most widely used tool for occupational radiation exposure monitoring is a badge worn on the trunk to measure $H_p(10)$ and $H_p(0.07)$ of photon radiation. Monitoring of exposure to beta and neutron radiations is performed for about 20% and 5%, respectively, of the workers occupationally exposed to radiation. Monitoring for internal deposition of radionuclides is, in general, less well regulated, and the results of internal dosimetry programmes are scarcely available. Dose to workers can also be determined from the results of workplace monitoring. In the case of aircrews, dose is normally computed on the basis of data on cosmic radiation fields and flight profiles. New techniques are emerging for the individual monitoring of external radiation. Active and passive electronic dosimeter systems are providing new dimensions for dosimetry and data handling, including direct dose readout capabilities and application of modern data networks. A number of problems remain to be solved. Neutron and beta dosimeters are not yet fully satisfactory. Internal dosimetry, still the subject of major research activities, has a need for more standardized routine programmes and systematic reporting. Monitoring for naturally occurring radioactive materials has to be improved and included in existing programmes. For global exchange, standards on dose record formats, and most particularly, unique quantities and units, are indispensable.

1. INTRODUCTION

Dose distributions of occupational radiation exposures and their trends are not only statistics of the radiation risk to the workers, but also a measure of the overall quality of the radiation protection infrastructure of a country. Thus, monitoring of radiation exposures is an important task. With increasing demand, the various methods and techniques used for monitoring have been improved continually and, for most applications, they have reached a quite satisfactory level. The international exchange of expertise and the wide availability of quality equipment (e.g. through the IAEA's Technical Co-operation programmes) contribute to the harmonization of occupational radiation monitoring standards and further worldwide accomplishments in radiation protection in general. Nevertheless, additional efforts are needed to improve remaining inadequate aspects and to fulfil new requirements.

2. INTERNATIONAL GUIDANCE AND RECOMMENDATIONS FOR OCCUPATIONAL RADIATION MONITORING

2.1. Monitoring programmes

Three Safety Guides [1–3], prepared jointly by the IAEA and the International Labour Office, provide guidance on fulfilling the requirements of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) with respect to occupational exposure. Two of these documents give specific guidance on the assessment of doses from external sources of radiation and from intake of radioactive materials, the other document deals with general advice on the exposure conditions for which monitoring programmes should be set up to assess radiation doses. In this last document it is stated:

> "Measurements related to the assessment or control of exposure to radiation and radioactive materials are described by the general term 'monitoring'. Although measurements play a major part in any RPP [radiation protection programme], monitoring is more than simply measurement; it requires interpretation and assessment. The primary justification for measurement must therefore be found in the way in which it helps to achieve and demonstrate adequate protection, including implementation of optimization of protection."
>
> ....
>
> "Thus, a programme of monitoring may be used for a number of specific purposes, depending on the nature and extent of the practice. These purposes may include:
>
> (a) Confirmation of good working practices ...and engineering standards;
> (b) Provision of information about conditions in the workplace and means of establishing whether these are under satisfactory control and whether operational changes have improved or worsened the radiological working conditions;
> (c) Estimation of the actual exposure of workers, to demonstrate compliance with regulatory requirements;
> (d) Evaluation and development of operating procedures from review of collected monitoring data for individuals and groups...
> (e) Provision of information that can be used to allow workers to understand how, when and where they are exposed and to motivate them to reduce their exposure;
> (f) Provision of information for the evaluation of doses in the event of accidental exposures.
>
> Furthermore, monitoring data may also be used:

(g) For risk–benefit analysis;
(h) To supplement medical records;
(i) For epidemiological studies of the exposed population."

2.2. Quantities and units for personal dosimetry

The International Commission on Radiological Protection (ICRP) and the International Commission on Radiation Units and Measurements (ICRU) have developed a hierarchy of quantities for radiation protection applications [4–7], which can be described by primary limiting dose quantities (protection quantities) and operational dose quantities.

The basic idea of a primary limiting (or protection) quantity is to relate the 'risk' of exposure to ionizing radiation (exposure due to internal and external radiation sources) to a single dose quantity. The quantities in which the dose limits given in the BSS are expressed are the effective dose E and the equivalent dose H_T in tissue or organ T. The quantity effective dose is generally considered to be an adequate indicator of the health detriment from radiation exposure at the levels experienced in normal operations. The protection quantities E and H_T relate to the sum of the effective or equivalent doses received from external sources within a given time and the committed effective or equivalent doses from intakes of radionuclides that occurred within that time.

For external exposure, operational quantities are defined for use in radiation protection measurements for area or individual monitoring. The operational quantities provide an estimate of effective or equivalent dose that avoids underestimation and excessive overestimation in most radiation fields encountered in practice [8, 9]. The operational quantities for area monitoring are ambient dose equivalent $H^*(\mathrm{d})$ and directional dose equivalent $H'(d, \Omega)$, where d is the depth in the ICRU sphere in millimetres. The operational quantity for use in individual monitoring is the personal dose equivalent $H_p(d)$ at the specific depth d in soft tissue. By using the operational quantities $H^*(10)$ or $H_p(10)$, approximate values for the effective dose are obtained. By using the operational quantities $H'(0.07)$ or $H_p(0.07)$, approximate values for the equivalent dose to the skin are obtained.

For internal exposure, however, other methods are used. Here, the term operational quantity is proposed to be used for committed effective dose $E(50)$, or committed equivalent dose $H_T(50)$ calculated with standard models [10, 11] and standard dose coefficients [12]. Committed effective dose and committed equivalent dose are calculated by multiplying intake by the appropriate dose coefficient. The intake is normally determined by in vivo measurements (e.g. whole body counting) and using standard metabolic models, by in vitro measurements of activity in excretion samples, or by direct aerosol deposition measurements of personal air samplers.

Total effective dose received or committed during any time period can be estimated by the sum of $H_p(10)$ and $E(50)$. Besides the few cases where single organ doses are of major concern, the determination of total effective dose is the primary objective of occupational radiation exposure monitoring. If the estimate of total effective dose is in the order of dose limits or above, an individual dose assessment for the protection quantities is indicated to replace the dose values of the operational quantities determined under standard conditions.

For the protection quantities as well as for the operational quantities the Système International (SI) unit is one sievert (Sv) [13]. For collective dose the unit one man-sievert (man·Sv) is used by the ICRP.

2.3. Dose records and registries

The BSS require that “Employers, registrants and licensees shall maintain exposure records for each worker for whom assessment of occupational exposure is required...” and that:

“Employers, registrants and licensees shall:

(a) provide for access by workers to information in their own exposure records;
(b) provide for access to the exposure records by the supervisor of the health surveillance programme, the Regulatory Authority and the relevant employer;
(c) facilitate the provision of copies of workers’ exposure records to new employers when workers change employment;
(d) when a worker ceases to work, make arrangements for the retention of the worker’s exposure records by the Regulatory Authority, or a State registry, or the registrant or licensee, as appropriate; and
(e) in complying with (a)–(d), give due care and attention to the maintenance of appropriate confidentiality of records.”

3. STATUS OF MONITORING PRACTICES

3.1. National legislations

The legal basis for monitoring occupational exposures varies significantly between countries. While individual monitoring is a strictly governmental task with given procedures and techniques in some countries (e.g. Germany), private companies run competing commercial dosimetry services in others, e.g. the United States of America. In some countries, for example Switzerland and the United Kingdom, the legal basis is given for approval of legal electronic dosimeters [14, 15]. However, even nowadays not all countries have specific regulations on individual monitoring. In particular, monitoring for incorporated radionuclides is only effectively regulated in a small number of countries [16].

Unfortunately, different quantities and non-SI units are still officially used in some countries, hindering ease of international communication, especially in education and training, and for persons working in different countries.

Wide variations also exist on procedures for registration and recording of dose data. While national dose registries have been set up in several countries, some others do not intend providing centralized dose records.

In most countries, the requirements on dose registration reflect the position of the regulator, which is interested in the occupational dose due to regulated practices. In contrast, the worker has an interest in his or her total dose, irrespective of the type and legal status of the source, e.g. natural radiation sources.

3.2. Quality assurance

Quality assurance in radiation monitoring is being approached in different ways. Depending on national legislation, procedures are more or less formal. In some countries, the whole dosimetry services have to be approved for their operation (e.g. Switzerland, UK), while in other countries the technical systems used have to pass given tests (e.g. Germany, USA). Besides the legal aspects of approval of a service, there are specific quality assurance measures recommended:

(a) Application of a quality management system and accreditation based on standard IEC/ISO 17025 has become widely used for dosimetry services.
(b) Participation in national, regional and international intercomparison programmes is an important element of quality assurance [17]. The IAEA is very active in this field. In the last few years several intercomparisons have been successfully organized for photon radiation [18] and internal dosimetry. Owing to the increasing number of participants in international programmes, the IAEA recommends and supports the organization of regional intercomparison projects.

3.3. Subject of monitoring

The total number of individually monitored persons exposed to human-made sources is estimated by the United Nations Scientific Committee on the Effects of Atomic Radiation to be 4.6 million, and the number of persons occupationally exposed to enhanced natural sources to be 6.5 million [19].

In Europe, a survey on external dosimetry was performed in 1999 [20], and one on internal dosimetry in 2002. From these data the percentages of different methods used in individual monitoring were derived. The data for external dosimetry are given in Table I.

TABLE I. PERCENTAGES OF INDIVIDUAL MONITORING METHODS USED FOR MEASURING EXTERNAL RADIATION IN EUROPE IN 1999 (100% = TOTAL NUMBER OF INDIVIDUALLY MONITORED PERSONS)

Radiation type	Location of dosimeter	Persons monitored (%)
Photon (X and gamma):	Trunk	~100
	Extremities	6.8
Beta:	Trunk	23
	Extremities	20
Neutron:	Trunk	5.6
	Extremities	0.6

The data on internal dosimetry are not complete for all countries, but it can be estimated that about 1–5% of the total number of persons individually monitored in Europe are monitored for incorporated radionuclides [21].

The data show that individual monitoring consists mainly of dosimetry for external photon irradiation of the whole body. Only very few individually monitored persons failed to receive a badge for photon radiation. This group consists mainly of workers handling soft beta emitters only.

Occupational dose distributions peak in general around the detection limit of the dosimetry system or at the dose level of the natural radiation background. This confirms that the purpose of individual monitoring for the majority of monitored persons is to verify that no exposure has taken place, and only for a small fraction of the monitored persons has a measurable occupational radiation dose to be determined.

The total number of dosimetry services worldwide is estimated to be in the order of 500. Most of these services are working in the field of external dosimetry, a much smaller number on internal dosimetry and some specifically on radon dosimetry.

The size of the dosimetry services varies from some ten customers to over one million customers per service. For the majority of services the number of customers is assumed to be in the range of some hundred to some thousand.

3.4. Monitoring techniques

3.4.1. External photon/beta radiation

There are three main techniques used for external dosimetry of photon/beta radiation:

(1) Photographic film,
(2) Thermoluminescence (TLD),
(3) Optically stimulated luminescence (OSL).

Until some 30 years ago, film was almost the only technique used. Since then there has been a continual trend towards using TLD. For extremity dosimetry TLD is used in almost all cases. Most recently, a significant shift from film to OSL has taken place in the USA [22] and in Japan [23].

On a smaller scale radio-photo-luminescence dosimeters (mainly in Germany and Japan), ion chamber based pen dosimeters and newly designed electronic dosimeters (see Section 4) are in use.

Modern systems generally fulfil the technical requirements for individual monitoring, with the exception of low energy beta radiation, where only a few systems are fully satisfactory [20].

3.4.2. Neutron radiation

For neutron dosimetry, two main techniques are used:

(1) Differential TLD measurements for thermal neutrons, e.g. ^{6}LiF/^{7}LiF albedo dosimeters;
(2) Track etch techniques, e.g. CR-39 for fast neutrons, and with converter also for thermal neutrons.

Until recently NTA film was a widely used neutron detector, but continued production was not guaranteed, prompting some services to replace their systems.

On smaller scales, bubble detectors and electronic neutron dosimeters (see Section 4) are used.

Individual monitoring for neutron radiation is still a challenge. Energy dependence of the response, sensitivity and dynamic range are limiting factors of most available systems [20]. These deficiencies may be somewhat eased by the fact that neutron dose values are usually rather low. Exceptions could be criticality accidents, which regained attention after the accident at Tokaimura, Japan in 1999.

3.4.3. Internal dosimetry

Determination of the type and amount of incorporated radionuclides is normally done by:

(a) In vivo measurement, e.g. by gamma spectrometry in a whole body counter;
(b) Analysis of excretion samples, e.g. by liquid scintillation counting, alpha spectrometry, mass spectroscopy (ICP-MS).

In some cases, inhaled activity is estimated by personal air sampling (see Section 3.4.4).

For assessment of committed dose, guidance is given by international organizations [11] and a variety of commercial software is available for dose calculation. In some countries the internal monitoring programme and the procedures used to estimate committed effective dose are well standardized [15]. However, in most countries, internal dosimetry is not yet fully regulated.

Within the European Union, most of the ongoing research projects in radiation protection are on internal dosimetry [24].

3.4.4. Workplace monitoring

Workplace monitoring includes measurement of radioactivity on surfaces and in the air as well as radiation field analysis. These methods normally complement individual monitoring. In some cases the resulting dose is not individually measured but derived from workplace monitoring methods. The most prominent application is dose assessment of aircrew. Nowadays, irradiation conditions at cruising altitudes are rather well known [25] and dose assessment may be performed by computation of dose rate as a function of altitude, geomagnetic latitude and longitude, and phase of solar cycle, combined with flight profiles and staff rosters. These calculations are supported or validated with measurements [26, 27].

For a large number of persons occupationally exposed to naturally occurring radioactive material, no individual monitoring is in place and the occupational dose can be estimated on workplace monitoring data only.

3.5. Biological dosimetry

If no dosimeters have been used or if high dose readings have occurred and are doubted, dose reconstruction by biological means may be indicated. The most developed biological method is chromosome analysis. Whole body irradiations above about 50 mSv can be assessed by this method. The procedure is very labour intensive and only a few laboratories are experienced in the application.

4. RECENT DEVELOPMENTS IN MONITORING METHODS AND TECHNIQUES

As explained in Section 2.1, the monitoring programme serves many more purposes than just assessment of dose. Therefore, the methods have always been optimized to offer additional information besides dose. A strong argument for using film or OSL dosimeters was their capability to render information on the irradiation conditions (estimation of photon energy, angle of irradiation, movement during irradiation, etc.). Recent developments with electronic dosimeters add completely new options [28–30], the most striking being that dose values can be made available immediately after the irradiation. With modern IT systems, this information is immediately accessible to all persons involved, allowing actions to be taken for specific actual situations in due time and the recorded dose attributed to work done in a given time and at a given location (so called 'job dosimetry'). In nuclear industries such 'operational dosimeters' have been used in parallel with the official passive dosimeters for a long time. Nowadays, modern technology allows the use of such electronic systems as legal dosimeters, omitting the annoying need to use two different dosimeters for the same radiation type. In Switzerland and the UK, legal electronic dosimeters have been approved for routine use [31, 32].

Electronic neutron dosimeters increasingly appear on the market. Most designs are handicapped by having very limited energy dependence and low sensitivity or bulky construction and high cost. New developments are more promising and in the near future a reasonable selection of commercial systems may be available [33].

In internal dosimetry, the main development over the last few years has been the establishment of specific regulations on internal monitoring programmes and of approval criteria for internal dosimetry services in a growing number of countries. Technically, the increased use of mass spectroscopy (e.g. ICP-MS) for the analysis of long lived radionuclides in bioassay samples is most prominent.

For aircrew dosimetry complete software packages have been developed and tested, such as CARI and EPCARD [27]. Dose computation is based on simulation of galactic cosmic ray incidence and cascade production of secondary particles. Some versions also include corrections from experimental data. The entry data are flight profile (altitude levels and duration), solar activity and flight trajectory (great circle approach).

The standard output data are in terms of effective dose E, but EPCARD also provides results in terms of ambient dose equivalent $H^*(10)$ and the contributions from high and low linear energy transfer components.

5. OUTLOOK

5.1. Dosimetry for photon radiation

Dosimetry for photon radiation comprises the bulk of dosimetric activities, attracting commercial companies to take over and control the market. Such large services have the advantage of well-developed and standardized methods and low cost for the customer. On the other hand, as a consequence of the commercial concentration of services, the local expertise in radiation dosimetry may diminish and the flexibility for site specific solutions may become limited. Also, it may not be easy for national authorities to verify the quality of foreign services operating in their region of responsibility and to receive feedback requested according to national legislation.

The techniques used for photon dosimetry have a high potential for undergoing a significant change in the near future. The use of passive or active electronic devices such as legal dosimeters in combination with the corresponding IT networks and software may change the practice of individual monitoring. However, the requirements for legal electronic dosimeters will have to be further specified, e.g. to separate functions of workplace monitoring (ambient dose rate indication, calibrated for the quantity $H^*(10)$) from measurement of $H_p(d)$.

5.2. Dosimetry for beta radiation

The main application of dosimetry for beta radiation is extremity dosimetry. New designs of detectors that are both comfortable to wear and less energy dependent are still needed. Active devices are still missing, but would attract some interest.

5.3. Dosimetry for neutron radiation

All available passive systems have some limitations and no immediate relief is expected. Further improvement of detector materials, together with sophisticated converter materials and evaluation procedures, may remedy the existing constraints. Electronic neutron dosimeters are emerging on the market. Their use may complement passive systems in various applications, but presumably not replace them.

5.4. Internal dosimetry

Establishment of internal monitoring programmes, quality assurance of incorporation measurements and standardization of routine dose calculation methods are needed. All measurement methods are subject to ongoing improvements, but real, new methods may be limited to the use of ICP-MS for long lived radionuclides.

5.5. Workplace monitoring/aircrew dosimetry

Workplace monitoring for dose assessment may increasingly involve measurements of radon and radon progeny. Such projects would need to be started to initiate expansion of the services needed.

For aircrew dosimetry, the main activities are conducted on the formal level to decide about procedures and software programs to be used. Measurements are needed mainly for verification of computed data.

5.6. Dose registries

Central registration of occupational dose enables the combining of exposures measured by different services for the same person and contributes to a standardized and simplified data exchange. It should be noted that values for $H_p(10)$ and $H_p(0.07)$ are needed for complete information on external exposure.

Most recent developments and announced future options of occupational radiation monitoring systems enable direct electronic readout of legal dosimeters. As a consequence, data networks become an increasingly important aspect of dose registering, reporting and record keeping. With the increasing mobility of workers, the importance of central dose registries becomes even more pronounced. To simplify international data exchange for workers, a standardized format (radiation passport) would be helpful.

6. CONCLUSIONS

Monitoring of occupational radiation exposures consists mainly of personal dosimetry for photon radiation. Adequate technical systems are widely available for this task and even more advanced techniques are just emerging on the market. Managerial and commercial criteria are increasingly dominating this application.

Monitoring of exposure to neutron and beta radiation and monitoring for internally deposited radionuclides are less developed and need further attention in research and development programmes as well as in standardization and regulation.

Monitoring of exposure to natural sources of radiation concerns a large group of workers and includes a wide variety of methods and techniques. Concepts and methods have to be further developed in this field to cover the need for occupational monitoring.

Standardized dose record formats and the use of only one type of quantity and unit for personal dosimetry would increase transparency and facilitate data exchange on occupational radiation exposure monitoring.

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RAPPORTEUR SUMMARY

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1. INTRODUCTION

Topical Session 4 deals with the monitoring of occupational exposure to ionizing radiation. The session comprises twenty presentations covering a varied selection of both general and technical domains. The papers have been organized into four categories, although they could just as well have been classified differently.

The areas covered by the presentations are: external dosimetry, internal contamination and internal dosimetry, measurement and quality.

2. EXTERNAL DOSIMETRY

There were eight presentations on this subject; six of which concern material and results, and the other two dealing with the interpretation of data.

Vanhavere and Deboodt [1] discuss a new generation of neutron bubble dosimeter used in Belgium. This type of dosimeter measures both thermal and rapid neutrons. It is calibrated with ^{252}Cf sources and by irradiation in the neutron flux of a reactor. Results of measurements taken on-site indicate whether a worker's irradiation levels are low. The presentation also stresses the constraints of using such dosimeters.

Prlić et al. [2] discuss the replacement, in Croatia, of traditional thermoluminescent dosimeters (TLDs) by a system of electronic digital ones. The aim was to lower the radiation doses, to quantify low doses and to obtain traceability of the dosimetric data. This type of dosimeter was tested by personnel in two different work situations: airport baggage control and nuclear medicine. In the second instance, the exposure is significant and requires surveillance.

The paper by Boshung et al. [3] presents a technological innovation — direct ion storage. This technique applies a passive electron dosimeter to beta emitters and photon emissions. An ionization chamber provides a direct reading of engaged dose equivalent for a wide range of doses. A comparative study carried out over a three month period with TLDs indicates a very good agreement with legal limits.

Hill et al. [4] present comparative study of two laboratories: one in Germany and the other in Kazakhstan. The study aims to validate programmes monitoring workers on a nuclear site.

The intercalibration carried out concerned external dosimetry and consisted of irradiating German dosimeters on both sites and taking readings in both institutes. The good agreement of the measurements was confirmed by a three month on-site campaign.

Another presentation tackles the problems of calculating the engaged dose equivalent in situations where radiation is either heterogeneous or multiple, or where the geometry of the measurements is unknown. Bakhanova and Chumak [5] have thus taken a mathematical approach based on the Monte Carlo method and have established coefficients between the dose measured and the engaged dose equivalent, specific to a given nuclear installation and dependent on the random position of the detectors.

Chau et al. [6] discuss a new generation of electronic neutron dosimeter developed in France by IPSN and which conforms to the ICRP Publication 60 recommendations as well as to the IEC 1323 standards. This dosimeter may be used to estimate the engaged dose equivalent as a result of radiation in a mixed gamma neutron flux. This detector is based on silicon technology which enables the indirect measurement of neutrons whose energy is converted into charged particles created after elastic dispersion and nuclear interaction. The paper presents the preliminary validation tests of this dosimeter, which is already on the market.

Manzoli and de Carvalho [7] discuss the manner in which dosimeters are prepared in Brazil, the equipment used and the expected advantages.

The final paper on external dosimetry is that of Schandorf et al. [8]. This presentation deals with the monitoring of external radiation for different categories of worker in Ghana (in industry, medicine and research) using TLDs. Monitoring was successfully carried out in conformity with the ICRP Publication 60 recommendations and facilitated by the automatic reading system of the dosimeters.

3. INTERNAL CONTAMINATION AND DOSE CALCULATION

The paper by Spitz et al. [9] is a technical presentation which could also have been included in the measurement section. It is difficult to measure X ray and low gamma energy coming from actinides deposited in the lungs after inhaling, especially if the thoracic wall is thick. The use of phantom calibrators available on the market does not allow the calibration of measurements for thoracic thickness greater than 4 cm. The authors have developed new layers which are placed between the detectors and the phantom. These polythene layers simulate the tissue absorption of muscle. Studies show that the variations in the efficiency of measurements could improve by 20% compared with extrapolated efficiency.

A paper on internal contamination is given by Bondarenko et al. [10]. Efforts to restore the Chernobyl reactor to an ecologically compatible radiological state are fraught with risks from radiation. In this case, the intervention is difficult, as movement stirs up previously sedentary radioactive aerosols, and there are numerous and major sources of radiation. The dosimetry of workers under these conditions is highly complicated.

A single, well-defined case of intake can be monitored easily, allowing a calculation of dose. However, things are very different for internal measurement when there are multiple and badly identified contamination sources and when there are multiple contributions to the internal dose. This paper shows the necessity, in these cases, of combining the results of bioassays with information on the actual intake circumstances in order to obtain the optimum estimation of the dose.

The paper by Bhati et al. [11] presents a mathematical model of the calibration of three Phoswich detectors used to measure the ^{241}Am on the surface of the skull. This study, based on the Monte Carlo method, simulates a phantom on two volumes: the skull surface and front. It provides an alternative to anthropomorphic phantom calibration. The study shows a good level of correlation between the theoretical curves provided by the detectors and the curves obtained using the Cristy's phantom, thus facilitating the calculation of doses received on bone surfaces.

4. NUCLEAR MEASUREMENT

Two papers deal with instrument optimization as a means of lowering the detection limits or the minimal detectable amount (MDA) and two papers discuss modelling and experimentation.

Gusev et al. [12] present an account of the methods used in the Russian Federation to lower the MDA by optimizing gamma measurement chains by measuring in a shielded cell. These operations enabled the MDA to be lowered by a factor of three, thus allowing the measurement of environmental samples in and around Russian nuclear sites.

Genicot et al. [13] discuss a study of the means which may be used to lower the detection limit of in vivo measurements. Three methods were explored: (1) adding a protective shield around the detectors, (2) working deep below ground, and (3) adjusting the size of the detector to the radionuclides to be measured.

Results show that it may be better to employ a well thought out optimization of the nature of the detector and its volume than to add protective shields or to conduct work in an underground laboratory.

Chumak et al. [14] discuss the method used to resolve the difficulties of taking gamma measurements during the renovation of the Chernobyl reactor. On this site, the doses delivered could be very high, the sources multiple and their positions unknown.

Traditional spectrometry is no longer possible because of the Compton front phenomenon and the downtime of equipment caused by extremely intense gamma fluxes. A mathematical method has been developed based on the Monte Carlo technique involving TLDs angled in various directions in space and protected by attenuators that provide each area with a three dimensional vectorial map of the gamma radiation flux. The efficiency of the model was confirmed by measurements taken using ^{137}Cs sources.

The paper by Dantas et al. [15] deals with the perfecting of calibration of X measurements in vivo. Indeed, in cases where ^{241}Am had been deposited in the skeleton and the liver then this may lead to an erroneous measurement for the lung. A matrix was constructed using several measurements of various organs of an anthropomorphic phantom, thus providing a system of equations which may be used to rectify pulmonary measurements influenced by deposits in other organs.

5. QUALITY

One way of proving one's competence in the field of dosimetry is to take part in an exercise of intercomparison. This topic formed the subject of the paper given by da Silva et al. [16]. An exercise piloted by the IAEA on measurements was carried out on irradiated dosimeters in three Brazilian laboratories. Results reported from the participating laboratories indicated that 5 out of 9 Latin American laboratories could meet the performance criteria, enabling the calculation of engaged dose equivalent for X and gamma emissions.

The paper of Souza-Santos and Hunt [17] discusses the quality system established at the Institute of Radiation Protection and Dosimetry and the results obtained to comply with ISO 17025 requirements.

In Switzerland, any laboratory wishing to work on dosimetry requires special accreditation. The paper of Valley et al. [18] presents the requirements for the practice of external as well as internal dosimetry. The authors especially underline the necessity of participating in external intercomparison exercises.

Azhar [19] discusses the requirements for obtaining accreditation to work in the field of ionizing ray dosimetry in Indonesia. The author discusses the types of ray to be measured, the frequency of the tests, the number of dosimeters to test for each category of ray and the performance criteria requirements in both routine and accident cases.

The paper by Mod Ali et al. [20] deals with the results obtained in Malaysia in the reduction of external radiation doses received by applying the 'as low as reasonably achievable' principle. The quality system and its traceability were also explained in this presentation.

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TOPICAL SESSION 4

DISCUSSION

M. TSCHURLOVITS: Little has been said about the uncertainty which is acceptable in personal monitoring. The uncertainty associated with different monitoring techniques varies, but it is always large, even in the case of external exposure monitoring. Has anything been done at the international level to determine what uncertainty is acceptable in personal monitoring for the purposes of occupational radiation protection?

K. FUJIMOTO: I believe that IAEA Safety Guide No. RS-G-1.1 entitled Occupational Radiation Protection goes into the question of uncertainty levels.

L. TOMMASINO: We are very good at measuring external exposures; there are thousands of institutions doing it. However, we are not good at measuring internal exposures. I am worried about that because of the risk of occupational exposure to NORM, which tends to mean internal exposures. Despite half a century of experience and research, the problem is a vast one owing to the different pathways and hence to the large number of resulting possible situations.

We need a strategy that applies to naturally occurring radiation and also to artificial radiation, and we need a simple conversion formula for internal dosimetry, because, when we are calculating internal doses, we need to be able to determine the external doses.

A.J. GONZÁLEZ: I should like to draw participants' attention to a change in the exposure monitoring obligation of States that is taking place at this moment.

The change derives from the additional obligation which States are assuming by becoming parties to international conventions. The Convention on Nuclear Safety, which has been in force for some time, requires that the Contracting Parties report on the occupational radiation protection of their populations, but it does not refer to occupational radiation protection standards. However, the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management (the Joint Convention) does refer to occupational radiation protection standards. Consequently, in November 2003, at the First Review Meeting of the Contracting Parties to the Joint Convention, each Contracting Party will be able to check whether the other Contracting Parties are reporting doses properly — in accordance with the scheme prescribed by the ICRU.

I believe that this change will lend great importance to intercomparison exercises, because States will have to use international units and quantities.

What has this got to do with the difficulties relating to internal exposures? I would recall that, with the International Basic Safety Standards, what you have to report on in the case of internal exposure is the intake. There is a formula for the conversion of intake into dose. That does not eliminate the difficulties relating to internal exposures, but it does reduce them.

Those of you who are from countries which have become Contracting Parties to the Joint Convention should perhaps inform your relevant authorities of the legal obligation which your countries will soon have as regards individual monitoring.

J. DUFFY: I would have been interested to hear whether any regulatory body has taken legal action against a licensee for failure to provide for individual monitoring, for failure to provide for area monitoring, for failure to provide for the calibration of monitoring instruments and/or for failure to keep records regarding individual monitoring, area monitoring and monitoring instrument calibration.

J.H. GÖTHLIN: With regard to the monitoring of workers for external irradiation, many people, for example, medical workers who simply administer radionuclides, are being unnecessarily monitored for very low external radiation doses.

In my view, only workers who are exposed to high levels of external radiation should be monitored, but the monitoring system should be capable of immediately detecting excessive dose rates and warning the worker. In medicine, people who work with fluoroscopy units are among those who should be monitored in this way.

In medicine, we are perhaps focusing too much on collective doses rather than on actual doses calculated with the help of phantoms or dose area product meters.

C.J. HUYSKENS: I agree with J.H. Göthlin. In situations characterized by very low individual exposures on an annual basis, there is hardly any need to have a precise figure for the individual level of exposure.

The ultimate goal of individual dosimetry, however, is not to have at the end of the year a precise figure for the effective dose equivalent or for whatever else you are interested in. It is not to demonstrate compliance with individual dose limits, but to demonstrate compliance with the standards that have been set; to demonstrate good practice. Consequently, in addition to individual dosimetry we have area dosimetry or workplace dosimetry and the resulting job related assessments provide very reliable information about the levels of individual exposure that may be expected.

Monitoring occupational radiation exposure is much more than just measuring individual doses.

K. FUJIMOTO: Unfortunately, measuring individual doses is all that can be done in some developing countries.

G.P. de BEER: There has been a lot of talk about integrating occupational protection against ionizing radiation into occupational protection against other risk factors. Is there anything being done to integrate radiological risk factors into a comprehensive system?

G.G. EIGENWILLIG: We have in Germany a compensation scheme for occupational diseases in uranium mining that takes into account, besides external and internal irradiation, risk factors such as quartz dust, arsenic, nickel, the off-gases from diesel engines and the off-gases from explosions.

M. BOURGUIGNON: The French Institute of Radiation Protection and Nuclear Safety (Institut de radioprotection et de sûreté nucléaire), which maintains a large database on occupationally exposed persons, has been having serious problems.

An identification problem arising from the misspelling of names has been largely resolved thanks to the fact that the Institute is now authorized to use people's national identification numbers — with a coding system.

Problems of identification and of obtaining exposure values persist, however, owing to the fact that the database includes information about foreign workers employed in France and French workers employed abroad, and there are no arrangements for the international exchange of occupational radiation exposure data.

Y. LAICHTER: I should like to know what various countries are using as recording levels for exposures?

K. FUJIMOTO: As far as external exposures are concerned, it appears from UNSCEAR's report for 2000 that in most cases, once an exposure is detected, it is recorded and then reported to UNSCEAR. So the recording level is the same as the detection limit.

R. WAKEFORD: I should like to question the widespread belief that there is no risk from external exposure to alpha radiation. Skin cancer is what I have in mind.

It all depends on the energy of the alpha particles and on whether they can reach cells which are sensitive as regards the induction of skin cancer. I say this because there has been a lot of discussion about the excess incidence of skin cancer among Czech uranium miners; about whether it might be due to alpha particles reaching sensitive cells.

K. FUJIMOTO: Alpha particles cannot reach sensitive cells in the case of people with normal skin and I doubt whether they can reach sensitive cells even in the case of people with abnormal skin.

Excess skin cancers among uranium miners are almost certainly due to something other than alpha radiation. They could be due to, for example, prolonged contact between the skin and asphalt.

J. LINIECKI: I believe that the excess incidence of skin cancer among Czech miners was observed only in one particular area and that it was attributed to the presence of arsenic in the air rather than to ionizing radiation.

G.G. EIGENWILLIG: As far as I know, the Czech literature attributed the excess incidence of skin cancer among miners to contamination with dust and to beta radiation, not to alpha radiation.

OCCUPATIONAL RADIATION PROTECTION IN MEDICINE

(Topical Session 5)

Chairperson

J. LINIECKI
Poland

OPERATIONAL RADIOLOGICAL PROTECTION AT MEDICAL INSTALLATIONS

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Presented by J. Barceló Vernet

Abstract

The largest group of individuals exposed occupationally to artificial radiation sources is that employed in health facilities. These individuals include: radiologists; radiation oncologists; other physicians who use X rays and radionuclides in their practices; other practitioners, such as dentists, paediatricians and chiropractors, who are licensed to use X rays; radiographers and radiological technologists who assist in the production of images and the management of patients; radiological physicists; installers; repairmen; and inspectors and regulators. The training and qualifications of these groups of users vary from country to country and from profession to profession. In most countries, recognized qualifications are a combination of governmentally set minimum standards and professional qualifications. However, some disciplines which are legally allowed to use X rays for medical applications have no training requirements for their members in this respect and in some countries the state of medical practice requires that those available learn about X ray uses on an ad hoc basis without any formal training or qualifications. There is no international authority which keeps records on the numbers, locations or qualifications of medical user groups. Some estimates put the number of 'qualified' physician users at about 200 000 and the number of radiographers/radiological technologists at perhaps 500 000. Taking all other medical radiation users into account, the total might reach close to a million people. International and national bodies have recommended maximum occupational exposures for radiation workers which apply to medical users. Modern X ray and isotope handling equipment is provided with built-in shielding and beam limitation devices. Radiation training, where it is provided, emphasizes good radiation hygiene, dose limitation, beam collimation and careful attention to image processing. The modern capabilities of imaging with ionizing radiation are such that the volume of medical usage increases significantly. Furthermore, some recently introduced diagnostic procedures have the potential to give unacceptable doses to patients and higher than acceptable occupational exposures to the physicians and technologists involved. Achieving the aims of the medical use of radiation with a minimum of risk both to patients and practitioners requires a continuing, multilayered approach involving both national and international health agencies and professional and educational organizations. A successful radiation safety programme is a calculated mix of education and regulation. The need is continual and a commitment of intent and resources is necessary.

1. INTRODUCTION

The use of ionizing radiation in medicine and industry began immediately after its discovery at the end of the 19th century. The first applications were carried out in the field of medicine and during the first half of the 20th century a whole host of new applications both for diagnostic purposes and for treatment were developed.

Radiological protection in the health care sector is connected to the progress that, little by little, step by step, has been incorporated into diagnostic and therapeutic processes. This technological development has gone hand in hand with tight control of all the parts involved, in order to reduce the risks inherent in the use of ionizing radiation and to make it an excellent tool offering more precise or accurate diagnoses and more effective treatment.

In recent years, there has been significant progress in both the technological development of medical equipment and in the development of new therapeutic procedures, this having led to a spectacular increase in the number of new practices.

In the field of radiotherapy, linear accelerators incorporating new digital technology have been developed because of the facilities they offer for the planning and administration of treatments, and which are capable of generating photons with energies of up to 2.5 MeV and allowing for optimum distribution of dose between target and healthy tissues. In the field of brachytherapy, there has been an important increase in the number of treatments, either through the use of automatic deferred load or remotely operated equipment, or by means of new manual procedures, e.g. for the implantation of ^{125}I seeds in prostate tumours. The annual number of teletherapy treatments in countries such as Spain is estimated to average around 1.1 per thousand inhabitants. In the case of brachytherapy, this average value is around 0.07 treatments per thousand inhabitants, and is either stable or shows very moderate growth rates.

In the field of nuclear medicine, and as regards image based diagnostic techniques, the use of high efficiency, high resolution gamma cameras has become widespread. These cameras are capable of obtaining tomographic images by means of isotopes emitting a single photon and by the implementation of techniques using positron emitting isotopes (PET), which has also meant the introduction of cyclotrons for the production of such very short lived, high energy isotopes (mainly ^{18}F). The radiopharmaceutical products used have evolved from those based on interaction at organ and tissue level to modern drugs based on interaction at cellular and intracellular level, using both traditional radioisotopes ($^{99}Tc^{m}$ and ^{131}I) and other new elements (^{90}Y). The annual number of diagnostic procedures in nuclear medicine in countries such as Spain is estimated to average around 12 per thousand inhabitants.

As regards techniques in nuclear medicine for therapeutic treatment through the administration of radiopharmaceutical products, and in addition to the generalized use of ^{131}I for the treatment of hyperthyroidism and thyroid cancer, there has been an increase in the treatment of pathologies of the joints with ^{169}Er, ^{186}Re and ^{90}Y and in the treatment of pain in cases of bone metastasis with ^{32}P, ^{89}Sr and ^{153}Sm. More recently, the introduction of radioimmunotherapy techniques has been initiated, based on the acquisition of monoclonal antibodies marked with isotopes such as ^{131}I, ^{186}Re or ^{90}Y, which show high degrees of uptake by tumour tissues. The annual number of therapeutic procedures in nuclear medicine in countries such as Spain is estimated to average around 0.2 per thousand inhabitants.

The in-vitro diagnostic techniques used in radioisotope laboratories at medical facilities have undergone similar development to that indicated for techniques in nuclear medicine, although the increase in the use of these techniques has been much more limited, owing to the appearance of alternatives not requiring the use of radioactive isotopes, this having led in some cases to the abandonment of certain practices.

In the field of radiodiagnosis, the use of computerized tomographic equipment has become widespread. The development of digital electronics has led to an important improvement in the quality of radiographic images and in the possibilities for treatment, giving rise to the emergence of new techniques in specific fields based on digital radiography. The annual number of radiological examinations for medical diagnosis in Spain is estimated to average more than 600 per thousand inhabitants.

In addition, the appearance of new techniques in specific fields based on the use of image based techniques with non-ionizing radiation such as magnetic resonance and the ecograph can help diminish the frequency of some procedures in radiodiagnosis.

The average annual number of interventions, either for diagnosis or treatment, for every thousand inhabitants in the world, according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report, is shown in the Table I.

TABLE I. AVERAGE ANNUAL NUMBER OF INTERVENTIONS WORLDWIDE

Medical technique	Number of treatments (per 1000 inhabitants)
Teletherapy	0.82
Brachytherapy	0.07
Diagnostic nuclear medicine	5.6
Therapeutic nuclear medicine	0.065
Medical radiology	330
Dental radiology	90

TABLE II. HEALTH CARE LEVELS WORLDWIDE

Medical technique	Health care level (treatments per 1000 inhabitants)			
	Level I	Level II	Level III	Level IV
Teletherapy	1.5	0.69	0.47	0.05
Brachytherapy	0.2	0.017	0.015	0.015
Diagnostic nuclear medicine	19	1.1	0.28	0.017
Therapeutic nuclear medicine	0.17	0.040	0.020	0.0004
Medical radiology	920	150	20	
Dental radiology	310	14	0.25	0.07

Dividing the population into four health care levels, the number of treatments for every thousand inhabitants, once again according to the UNSCEAR 2000 Report, is shown in Table II (Level 1 is that of those countries with greater health care infrastructures).

A technique that has recently emerged, and one which is finding increasing use in specialities such as vascular surgery, is interventionist radiology. This technique, to the extent to which the intervention is carried out under radioscopic control and near to the patient, normally implies high risks of radiation exposure for the professionals involved, given that very often the time of use of the X ray equipment is rather prolonged. To this difficulty, and inherent to the very technique, must be added the fact that very often the interventionist procedures are carried out by specialist doctors who have not generally been trained in the uses and techniques of protection against ionizing radiation.

The international organizations involved in the myriad aspects of radiological protection, while recognizing the benefits of this technique for medicine, express concern for the risks implied.

The International Commission on Radiological Protection (ICRP) has issued recommendations on how to decrease radiation injuries resulting from ionizing radiation procedures.[1]

In 2000, the World Health Organization published the document entitled Efficacy and Radiation Safety in Interventional Radiology, and more than a third of

[1] INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION, Avoidance of Radiation Injuries from Medical Interventional Procedures, Publication 85, Pergamon Press, Oxford and New York (2000).

the papers presented at this Topical Session deal with radiological protection in interventionist radiology.

In Spain, there are a total 344 authorized radioactive medical facilities: 106 for radiotherapy, 148 for nuclear medicine, 6 cyclotrons for the production of very short lived positron emitting isotopes and subsequent synthesis of the corresponding radiopharmaceutical product, fundamentally fluorodeoxiglucose, with ^{18}F (FD6) in PET installations, and 84 laboratories for radioimmunoanalysis and blood sterilization. Furthermore, there are 84 laboratories for teaching and medical research.

The number of X ray facilities for medical diagnosis amounts to 20 578; of these, 14 601 are dental diagnosis installations (71%) and 1505 veterinary radiodiagnosis installations (7%). At these facilities more than 30 000 radiodiagnostic units are employed.

The control of all these installations is exercised by the Spanish Nuclear Safety Council (CSN), which is the domestic regulatory authority and the sole body responsible for nuclear safety and radiological protection. The number of radioactive medical installations operating in Spain has remained stable over the last six years, as has the percentage of X ray facilities for dental and veterinary diagnosis.

2. RADIOLOGICAL PROTECTION IN RADIOACTIVE MEDICAL INSTALLATIONS

In medical installations, ionizing radiation is used to obtain a benefit for society with a minimum radiological risk to humans. To reduce this risk to an acceptable level it is necessary to work in two fields: (1) the maintenance and enhancement of safety and protection measures for equipment and radioactive sources, and (2) the training of workers exposed during their professional duties.

2.1. Maintenance and enhancement of safety and protection measures for equipment and radioactive sources

The work in this field has several phases:

(a) In the design, manufacture and correct operation of equipment containing radioactive sources and of ionizing radiation generators;

(b) At the installation itself, including correct design of the facilities, their distribution, positioning of the equipment, areas to be protected and shielding, as well as in acceptance testing and the establishment of quality assurance programmes, oriented or aimed at reducing exposure and optimizing every aspect of radiological practice, such that this practice be effective for diagnosis or treatment with the lowest possible doses;

(c) During operation itself, ensuring suitable protection of all the personnel, suitable use of the equipment and radioactive material, optimization of working methods and the performance of regular checks of non-encapsulated radioactive material, encapsulated radioactive sources, radioactive equipment and generators of ionizing radiation and of the installations as a whole.

2.1.1. Technical aspects relative to the safety of equipment and sources

The regulatory authority of each country has to carry out documentary checks on the adequacy of the design of equipment, on the results of the tests carried out on such equipment prior to its operation, in order to ensure compliance with the manufacturer's specifications, and on repairs and maintenance operations performed during the service lifetime of the installations. At the same time, documentary and physical checks (measurements) have to be carried out during pre-operational inspection of the installation and during monitoring inspections.

With respect to encapsulated radioactive sources, in addition to checking for the existence of certificates of activity and hermetic sealing on the part of the manufacturer, it is necessary to include in the conditions established for operation of the facilities the requirement that tests be carried out at regular intervals by a competent authority, in order to guarantee the hermetic sealing of the sources and the absence of surface contamination. At the same time it is desirable that suitable agreements for the return of unused radioactive sources be reached with the supplier or, in its absence, with an authorized entity.

In installations with electromedical equipment, such as linear accelerators, remote cobalt therapy units, cyclotrons, high dose level brachytherapy equipment, etc., it must be established that the aforementioned equipment cannot be used until all the necessary predelivery tests and adjustments have been made (acceptance testing) and a training programme given by the supplier company, including a demonstration of the operation of the apparatus and instructions on its correct handling. Likewise, pre-operational geometric and dosimetric checks should be carried out, along with preliminary verification of the shielding of the bunkers.

In the European Union (EU), the criteria applicable to quality in radiodiagnosis, radiotherapy and nuclear medicine are included in Directive 97/43/Euratom on medical exposure.

In Spain, the standard on quality assurance in diagnostic radiology, arising from incorporation of the aforementioned directive, establishes the obligation that the supplier carry out acceptance tests on the equipment, guaranteeing compliance with the purchasing specifications and with the appropriate technical standards. It also establishes that these tests should determine the initial conditions of the equipment as a benchmark for subsequent quality controls. These should be carried out using accepted quality control protocols. Furthermore, it includes a series of criteria and parameters regarding the acceptability of these installations, which must be met when the equipment is checked. Non-compliance with these criteria and parameters, if correction or repair is impossible, implies that the equipment must remain out of use.

2.1.2. Technical evaluation of installation design

The evaluation should be based on the documents drawn up by the licensee and should comply with the legislation in force with respect to safety and radiological protection. The evaluation has to be carried out in accordance with the criteria and the methodology specified in technical procedures and in general covers the following:

(a) The project and design of each installation;
(b) The classification and distribution of the areas and working conditions;
(c) Building materials and, with respect to these, the assessment of shielding coating;
(d) Decontamination methods;
(e) Environmental radiological surveillance systems;
(f) Ventilation systems;
(g) Safety of equipment and radioactive sources;
(h) Safety systems associated with the installation;
(i) Work procedures, both for normal conditions and for incidents or accidents;
(j) On-site and off-site emergency plans for major hospitals;
(k) Radioactive waste management;
(l) Organization and responsibilities;
(m) Personnel training and licensing.

In the specific case of external radiotherapy installations, it is required that the technical evaluation include checking that the equipment and the installation are equipped with safety switches and interlocks guaranteeing the interruption of radiation emissions in situations where undue risk might exist (opening of doors in irradiation enclosures, internal pushbutton if radiation begins with people inside the enclosure, high levels of radiation indicated by area monitors).

At the same time, it is necessary to check for the existence of radiation detectors suitable for environmental radiological surveillance, the placement of fixed detectors and the presence of contamination detectors when these are required.

Before operation of the installations, the regulatory authorities must carry out an inspection to check that the installation fulfils all the requirements in place to ensure correct operation. In Spain, this visit is obligatory.

2.1.3. Radiological protection in operating installations

In the operation of radioactive medical installations, special attention is paid to ensuring that the number of people exposed be as few as possible and that the dose limits never exceed the values established by the legislation in force.

The regulatory authorities are required to check that the work areas in each type of installation are duly classified and signposted, and that the personnel working in the aforementioned areas are duly classified. In addition, it is necessary to check for the existence of systems for the radiological surveillance of personnel and the recording of the doses received.

In the EU, compliance with Directive 96/29/Euratom is obligatory. This Directive establishes the basic standards governing the health care protection of the workers and the population in general against risks arising from ionizing radiations, and has been incorporated into Spanish legislation in the regulations on protection against ionizing radiations.

In Spain, CSN carries out regular inspections of radioactive medical installations, performing the following documentary checks: recording the results of periodic inspections of equipment and of the sealing of sources and, if appropriate, annotations in the operations log on the equipment with respect to breakdowns, repairs, incidents and periodic safety checks.

Similarly, the following physical checks are carried out: checking changes in the initial positioning of equipment, operation of switches, safety interlocks and luminous indications; checking levels of radiation issued by the equipment and background levels in the different areas of the installation; and checking levels of radiation and contamination and the existence of, and compliance with, working procedures for both normal and incident, accident or emergency situations.

2.2. Training of workers in radiological protection

Traditionally, all sectors involved in practices in which there is a risk of exposure to ionizing radiation have recognized that training in radiological protection is a key element for obtaining and maintaining an adequate safety culture, both among individuals and among the organizations involved in work in the presence of radiation. Moreover, training contributes to improving the technical competence of individuals and organizations.

Aware of the importance of the above, the regulatory authorities have introduced specific requirements relating to the qualification and training of workers in the regulations applicable to radioactive installations.

In the EU, Directive 90/641/Euratom on the operational protection of external workers with a risk of exposure to ionizing radiations as a result of interventions in the controlled zone establishes the obligation that the external companies employing such workers give them basic training in radiological protection, as necessary for their work, as well as establishing the obligation that the licensees of the installations at which they work give these workers specific training, taking into account in all cases the specific characteristics of the installations and the specific work to be carried out.

Directive 96/29/Euratom, which establishes the basic standards on the protection of workers and the population against the risks arising from ionizing radiations, includes requirements on training in radiological protection for all workers who suffer the risk of exposure during their working day. In this respect it is important to ensure that all the people working at the installations know the standards for protection against radiation and the actions to be taken in the event of an emergency, assigning to the licensee the obligation to define the necessary level of knowledge and specialization of each worker and to develop training programmes aimed at providing such knowledge and specialization. At the same time, the licensee is required to give the workers training in radiological protection both before initiation of their activities and periodically thereafter, depending on the degree of their responsibility and the risk of exposure in their place of work.

In Spain, the first regulation governing nuclear and radioactive installations, issued in 1972, establishes the basis of the training requirements for the operating personnel of radioactive installations. For people managing or operating X ray installations for the purpose of medical diagnosis, the training requirements are established in the regulation governing such installations, which was issued in 1992.

In both cases, a system of individual certification of the qualification of these workers by the regulatory authority is contemplated, through the granting of a personal licence on completion of training courses approved by CSN, in accordance with the rules established in the Council's Safety Guide (1998) on Standardisation of Training Courses for Radioactive Installation Supervisors and Operators.

The new Regulations on Nuclear and Radioactive Installations, issued in December 1999, complete the definition of the qualification and training requirements applicable to the workers, establish the personal nature of the operating licence for radioactive installations and its awarding for specific fields of application, and identify two alternative ways of obtaining the licence: by sitting an examination before the licensing board or by successful attendance at courses authorized by CSN.

Although, to date, training methods in radiological protection have fundamentally consisted of attending courses, current computer resources open up a wide range of possible new methods that might help significantly to facilitate training in radiological protection and broaden its use. There are at present various initiatives for the development of teaching materials using interactive elements and even virtual reality. Moreover, the internet means that training courses of this type may be undertaken in the home, as already happens with other disciplines. In Spain, CSN will be promoting these initiatives over the coming years and is even studying the possibility of standardizing them for the granting of personnel licences and accreditations.

3. WORKER DOSES

The results of personnel dosimetry readings show that the working practices and methods are increasingly safe.

Table III shows the average individual dose incurred by workers at radioactive medical installations, included in the UNSCEAR 2000 Report, for the period 1990–1994. Both the overall data for all workers worldwide and data for the workers of OECD member countries, excluding the United States of America, are shown. Finally, data for Spanish workers are also presented, in this case for the year 2001.

It is important to note that the UNSCEAR data have been averaged over the period 1990–1994, which implies the need for exercising great caution when comparing the data. These data are displayed graphically in Fig. 1. The evolution over time of doses for various medical techniques, according to the UNSCEAR 2000 Report data, is summarized for the totality of the world's workers in Table IV.

It may be observed that, in spite of the increasing use of ionizing radiations in medicine, the dose has followed a downward trend over the years.

Table V shows the regional dose distribution for the period 1990–1994 according to the information provided by the UNSCEAR 2000 Report, taking into account exclusively those workers with significant (measurable) doses.

With reference to Spain, of the total 85 284 workers subject to dosimetry controls during 2001, 67 332 (79.7%) carry out their work at medical facilities. The average individual dose for the workers in radioactive medical installations in 2001, according to data in Spain's National Dosimetry Bank, was 0.75 mSv/a; lower than that of the workers in nuclear power plants, facilities in the decommissioning and dismantling phase, industrial radioactive facilities and transport. Only the radioactive

TABLE III. AVERAGE INDIVIDUAL DOSE INCURRED BY WORKERS AT RADIOACTIVE MEDICAL INSTALLATIONS

Medical technique	Average individual dose incurred (mSv/a)		
	Spain 2001	OECD	UNSCEAR
All medical practices	0.75	1.1	1.3
Radiodiagnosis	0.64	0.9	1.4
Radiotherapy	0.61	0.65	1.38
Nuclear medicine	1.84	1.23	1.68

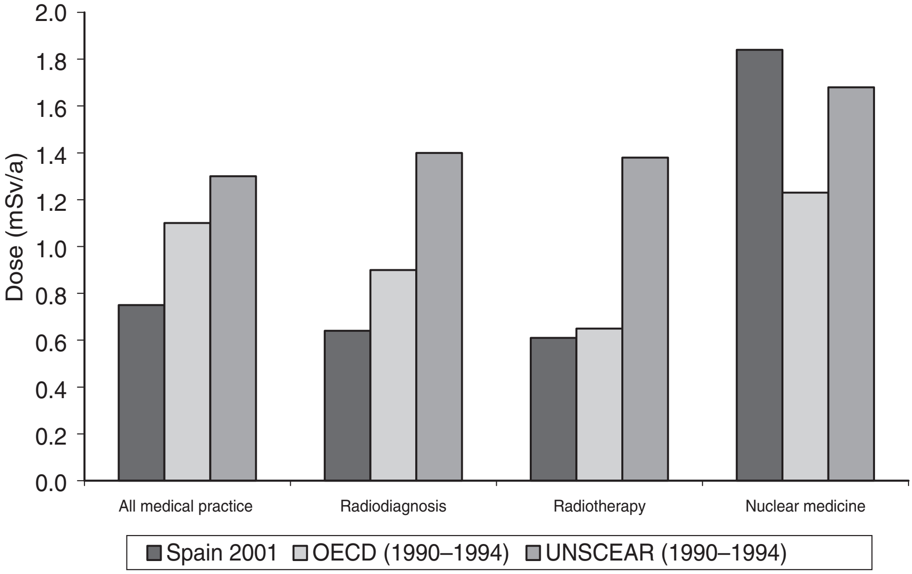

FIG. 1. Average individual dose incurred in radioactive medical installations.

installations used for research and teaching and the fuel cycle and waste facilities gave lower values for average individual dose. In radioactive medical installations, the workers show average individual doses close to those of workers in the medical applications sector overall, except in the case of workers at nuclear medicine facilities, who show average individual doses of almost double that value.

The dosimetry readings for Spanish workers in different medical fields in 2001 are summarized in Table VI.

The evolution of average individual doses (only those workers with significant doses are considered, cases potentially in excess of the annual dose limit being excluded) in Spain between 1995 and 2001 is shown in Fig. 2.

TABLE IV. EVOLUTION OVER TIME OF DOSES FOR VARIOUS MEDICAL TECHNIQUES (SOURCE: UNSCEAR 2000 REPORT)

Medical technique	Average individual dose (mSv)			
	1975–1979	1980–1984	1985–1989	1990–1994
All medical practices	0.78	0.60	0.47	0.33
Radiodiagnosis	0.94	0.68	0.56	0.50
Nuclear medicine	1.01	1.04	0.95	0.79
Radiotherapy	2.23	1.58	0.87	0.14

TABLE V. REGIONAL DISTRIBUTION OF DOSE FOR PERIOD 1990–1994 (SOURCE: UNSCEAR 2000 REPORT)

Region	All medical practices		Radiodiagnosis		Nuclear medicine		Radiotherapy	
	No. of workers	Average individual dose (mSv)	No. of workers	Average individual dose (mSv)	No. of workers	Average individual dose (mSv)	No. of workers	Average individual dose (mSv)
East and southeast Asia	15 943	1.56	13 925	1.63	320	1.22	1593	1.12
Eastern Europe	11 091	1.25	8155	1.20	1607	1.01	1387	1.54
Indian subcontinent	10 220	1.44	6282	0.80	634	4.12	2515	1.81
Latin America	6308	3.30	4776	3.32	632	3.89	667	3.19
OECD (excluding USA)	112 847	1.10	20 763	0.90	3982	1.23	3187	0.65
Others	1226	4.69	1051	4.42	455	1.72	63	4.60

TABLE VI. DOSIMETRY READINGS FOR SPANISH WORKERS IN DIFFERENT MEDICAL FIELDS IN 2001

Medical technique	No. of workers	Collective dose (man·mSv)	Individual dose (mSv/a)
All medical practices	67 332	33 081.35	0.75
Radiodiagnosis	40 570	15 717.27	0.64
Radiotherapy	2161	855.62	0.61
Nuclear medicine	1862	2821.76	1.84

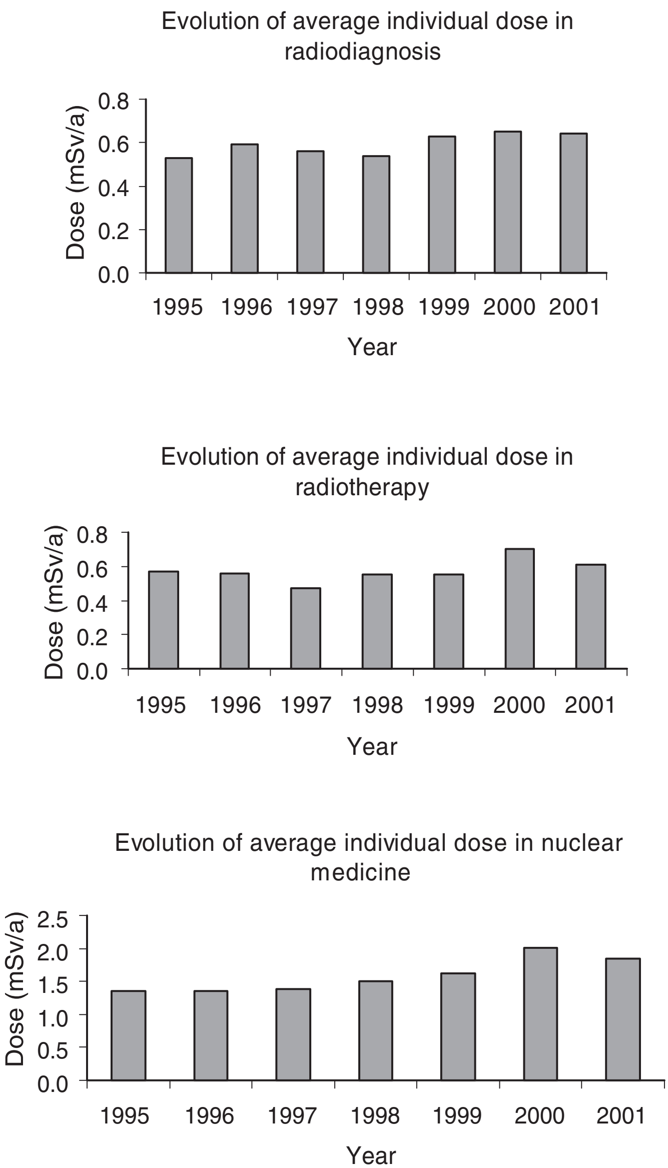

FIG. 2. Evolution of average individual dose in Spain over the period 1995–2001.

4. PROTECTION OF THE PATIENT

Medical interventions should offer a sufficient net benefit, a balance being established between the diagnostic or therapeutic benefits that arise and the possible detrimental effects for the individual that they may cause.

To ensure compliance with the recommendations of the ICRP, and in agreement with what is established in the Directive 97/43/Euratom in medical practice, it is essential that all the exposures received in medical intervention fulfil the following conditions: they must be justified, they must be performed so as to give the lowest possible dose to the patient, and they must be carried out under the direction of a specialist doctor who assumes responsibility.

With respect to radiological protection, both the doctor in charge of the examination or treatment and the prescribing doctor each have a responsibility. For this reason, they must both have suitable and continuous training as necessary in this area.

At the International Conference on Radiological Protection of Patients in Diagnostic and Interventional Radiology, Nuclear Medicine and Radiotherapy, organized by the IAEA and held in Málaga, Spain, in 2001, a series of conclusions was reached regarding reduction of the doses potentially received by patients through the establishment of quality assurance programmes, including the controls to be carried out on the equipment, and, fundamentally, the preliminary and on-going training of all the professionals involved. Also underlined was the fact that around two billion diagnostic examinations with X rays are carried out annually throughout the world, along with 32 million nuclear medical diagnoses and 5.5 million radiotherapy treatments. At the same time it was pointed out that in interventionist radiology, and given the fact that these are highly complex procedures, very high doses are generally furnished to the patients and incurred by the professionals, owing to the high radioscopy times involved.

Worthy of special mention is the material presented at that conference with regard to in-utero exposure. Particularly significant is the establishment of a threshold dose for malformations of 0.1 Gy. In the case of pregnant women between weeks 8 and 25, there is a very high risk of mental deficiency occurring with doses in excess of 1 Gy and, a fundamental point, it was pointed out that there were objective data suggesting that the interruption of pregnancy was not a necessity with doses of up to 0.1 Gy.

Finally, in Spain, quality assurance programmes are being implemented in radiotherapy, nuclear medicine and radiodiagnosis with a view to ensuring compliance with the aforementioned Directive (97/43/Euratom), which has been incorporated completely into Spanish legislation. In Spain, compliance with this Directive is the responsibility of the health authorities.

5. FUTURE ACTIONS

In general, and as the International Radiological Society points out, achieving the objective that is intended in the use of radiation in medicine implies incurring the minimum possible risk both to patients and professionals and requires intense collaboration between international agencies, governmental regulatory bodies and professional bodies. This implies a suitable combination of training and regulation, bearing in mind that the point of departure varies greatly from one country to another, with respect both to demands regarding qualifications and training and to regulatory aspects. In spite of this, the indicators show a trend of improvement in occupational radiological protection in medicine, accompanied by the emergence of new problems due to technological progress, as may be observed, for example, in interventionist radiology or in the use of digital technology.

The following, among others, may be singled out as tasks requiring time and effort by all those involved in occupational radiological protection in the health care sector:

(a) Standardization of practices used in different countries in relation to the recording and reporting of dosimetry data, with a view to improving comparative analysis, at international level, of occupational doses received at medical radioactive installations;
(b) The promotion of training activities in relation to radiological protection, aimed at all exposed workers and, specifically, at providing more intensive training for specialists in nuclear medicine and for those involved in other specialities in which interventionist procedures are performed (cardiology, radiology, vascular surgery, etc.);
(c) Methods to reduce occupational doses associated with relatively high risk procedures such as interventionist radiology;
(d) Analysis of the variation in occupational dose, depending on the different types of radiological equipment used and on their conditions of use;
(e) Training in radiological protection for prescribing doctors such as paediatricians, family doctors, gynaecologists, etc;
(f) Analysis of possible actions for the reduction of occupational doses at nuclear medical facilities, which are the highest in the medical sector, taking into account the forecasts for an increase in procedures due to the spread of PET techniques and the introduction of new isotopes, and to modifications in the management of supplies of radiopharmaceutical products to the installations (radiopharmacy);
(g) Methodology and new designs of dosimeters for the measurement of occupational doses in sterile environments (optimization of hand dose measurement in operating theatres).

RAPPORTEUR SUMMARY

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1. INTRODUCTION

Topical Session 5 on Occupational Radiation Protection in Medicine consists of 16 contributed papers originating from 15 countries. For the purpose of presentation, the papers are grouped together, somewhat arbitrarily, into three fields: (1) personnel monitoring of medical workers (7 papers), (2) radiation protection in interventional radiology (3 papers), and (3) miscellaneous applications (5 papers).

An attempt is made here to present the common issues and areas of disagreement between the papers and to avoid, as far as possible, a paper-by-paper summary.

2. PERSONNEL MONITORING OF MEDICAL WORKERS

The papers on this topic present the experiences gained in several countries: Romania [1], Estonia [2], Sudan [3], Saudi Arabia [4], Ukraine [5], Brazil [6], Argentina [7] and the Russian Federation [8].

Common aspects of the experiences include:

(a) Legislation in all the countries is in accordance with the basic principles of the International Commission on Radiological Protection and the recommendations of the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. Several contributors describe the methods used to implement these recommendations in their national organizations.

(b) While the metrological aspects of monitoring are not specifically described, a trend to replace film by thermoluminescent dosimetry is observed over the survey period.

(c) Comparing dose distributions is not straightforward. If the mean dose to workers is used, this quantity depends on the criteria used for monitoring workers and also on the categorization of work sectors. For all the groups studied the mean dose lies between 0.5 mSv/a and 3 mSv/a — with the exception of some angiographers and cardiologists in Estonia (mean annual dose around 9 mSv) and medical personnel working as nurse-handlers of radiocative sources in Ukraine (mean annual dose around 6 mSv).

(d) The aspect of dose reduction is addressed by most contributors, with some papers demonstrating a reduction during the survey period and others proposing strategies for the future. All the contributors consider that opportunities exist for improving radiation protection.

(e) Several authors point out that dose monitoring of workers is not optimal. Often, dosimeters are not worn systematically and more extensive use of extremity dosimeters is suggested.

Areas of disagreement include the following:

(a) The frequency of individual monitoring can be carried out monthly or quarterly; no international recommendation exists to define what is good practice.

(b) Dosimeters are worn in different ways when lead aprons are used. Several international recommendations suggest that dosimeters be worn under aprons in order to obtain a measurement representative of the effective dose received by the wearer. Alternatively, and even better for operators with a high fluoroscopy workload, two dosimeters can be worn, one under and one over the apron. In contrast, some national legislation recommends wearing a single dosimeter over the apron — an example being Brazil. Doses recorded by dosimeters worn over and under aprons cannot be compared; for this reason it seems necessary to specify in each dose report where the dosimeter was worn and whether or not a lead apron was used. When dosimeters are worn under and over an apron, both dose values should be used to estimate effective dose.

(c) Workers are categorized differently in different countries. This reflects differences in hospital systems and professional roles between countries, but these differences when combined with varying criteria for personnel monitoring make dose comparison difficult. Improvement is needed in these areas.

In summary, although mean annual doses in medical practice are generally far below dose limits (about one tenth of the limit), personnel monitoring of medical staff is a task that presents special problems and one that needs further development. Areas for improvement include extremity dosimetry, systematic wearing of dosimeters and standardization of worker categories.

3. RADIATION PROTECTION FOR INTERVENTIONAL RADIOLOGY

Papers on radiation protection for interventional radiology have been contributed by Poland [9], Spain [10] and Egypt [11]. The main problems discussed in the contributions are:

(a) Dose rates near the equipment used in interventional radiology are high, mainly due to radiation scattered at the patient entrance surface. Scattered air kerma (K_{sc}), expressed in mGy, is described simply by:

$$K_{sc} = \alpha \frac{\text{KAP}}{d^2}$$

where
KAP is the kerma–area product (Gy/cm^2),
d is the distance to the entrance surface,
α is the scatter contribution (~3 × 10^{-2}).

So for a standard fluoroscopic examination (KAP ~100 Gy.cm^2), the dose to the operator's shoulder (distance ~0.5 m) is about 1 mSv (confirmed by Vano et al. [10]). For a mean distance to the operator of 1 m, the dose is about 0.25 mSv per examination. Assuming 400 examinations per year, the annual dose without protective tools is about 100 mSv, far above the dose limit. For irradiation of the hands, a mean distance of 20 cm to the radiation field corresponds to a hand dose of about 10 mSv per examination, or around 4 Sv/a. Again this is far above the dose limit of 500 mSv. Jankowski et al. [9] report values of about 500 mSv from preliminary studies.

(b) Suggested tools for radiation protection are ceiling suspended screens, under table curtains, mobile lead barriers and lead clothing. Reduction factors have been measured by Kamal et al. [11]. The efficiency value reported by Kamal et al. for a lead apron (reduction factor 5) is different to that reported by Vano et al. (reduction factor ~20), showing the effects of different designs of lead apron. Several authors comment that protection tools have yet to be optimized (curtain thickness, weight of the aprons, etc.).

(c) Jankowski et al.'s [9] study of hand exposure shows an asymmetric right sided distribution covering two orders of magnitude with a maximum dose in the range of 50–500 mSv per month accounting for 0.2% of the results. The authors report that dose variability is related to the type of procedure, operator skill and equipment performance, and recommend that routine hand dosimetry be compulsory for interventional radiology workers.

(d) The attitude of physicians towards radiation protection is discussed by several authors. This is a critical point and in some cases "dosimeters are not worn to avoid troubles with the regulatory authority in case of exceeding of dose limits". A major effort is required to inform physicians and to motivate them to respect radiation protection precautions.

In summary, the papers present important aspects of the critical problems related to operator exposure in fluoroscopy. Numerical values are given that are really needed in the field. However, the approach is not very invasive. Physicists seem to be just tolerated and the optimization of the radiological procedure as a whole is not really tackled even though this would be of benefit to both the patient and the operator.

4. MISCELLANEOUS APPLICATIONS

Each of the four papers in this section is devoted to a special application, so they must be presented separately.

The use of beta sources in coronary brachytherapy is discussed by Prieto et al. [12]. Two different systems are used: β-Cath from Novoste ($^{90}Sr/^{90}Y$) and Galileo from Guidant (^{32}P). For radiation protection of the operators, only the dose rate at the surface of the brachytherapy source container (about 1 mSv/h) is important. The exposure during the application and source transfer is very low. The main protection issue is the increased fluoroscopy time associated with the brachytherapy procedure.

The skin dose received by operators during beta source application in radiosynoviorthesis (^{188}Re source) and vascular brachytherapy ($^{90}Sr/^{90}Y$ source) has been assessed by Barth and Mielcarek [13]. Exposure arises from contamination of the operator's skin for the rhenium application (up to 200 mSv) and from external irradiation for the strontium source (up to 1 mSv). The authors recommend that extremity dosimeters be worn for this kind of procedure and that the dosimeters be calibrated to measure beta radiation.

Kamenopoulou et al. [14] studied the dose to operators in nuclear medicine laboratories in Greece. Doses are of the order of 1–3 mSv, depending on the type of application (higher doses are associated with therapeutic applications) and on the type of laboratory, public or private. Doses in the private sector are higher than in the public sector because of different workloads. The authors suggest an original step, defining dose constraints corresponding to levels below which individual doses for 75% of exposed workers should be included.

Al-Haj et al. [4] present trends in personnel exposure from 1994 to 2001 at a large medical centre in Riyadh. In the radionuclide production sector (cyclotron), individual doses for operators and radiochemists have increased between 1994 and 2001 from 3 mSv/a to 10 mSv/a. The increase is attributed to equipment breakdowns that occur more frequently as the equipment ages. In nuclear medicine a 25% increase in the mean annual dose is observed. This is associated with a reduced number of staff and a constant collective dose. For cardiac catheterization procedures, replacement of continuous exposure fluoroscopy units by pulsed mode units with an image freeze feature between 1997 and 1998 halved the mean annual dose (from 2 mSv/a to 1 mSv/a).

Operator dose for computerized tomography guided lung biopsy has been studied by Nishizawa et al. [15]. To begin with, the operator dose was 10 mGy/min to the hands and 6 μSv/min was the effective dose. By lowering the tube voltage (from 120 kV to 80 kV while increasing the current from 50 mA to 75 mA) and using a needle holder, the operator hand dose was reduced by a factor of 50. It must be underlined that the patient also benefits from lowered tube voltage.

In summary, in this section it is apparent that numerous special applications arise in medical practice that require particular analysis of radiation protection methods. There is the potential for substantial dose reduction.

5. CONCLUSIONS

It was not possible to present all aspects of the contributions. For instance, the paper by Kalnitsky et al. [8] provides a detailed account of the evolution of radiation protection in the Russian Federation (number of personnel, examinations, X ray imaging systems), which could not be easily summarized.

The information presented in this session is important. Further work still needs to be done, particularly in educating and training physicians.

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TOPICAL SESSION 5

DISCUSSION

J. LINIECKI: In developed countries, conventional radiology no longer presents serious risks to operators. The risks lie mainly in the newer, high dose procedures. Fortunately, they are applied in hospitals, where the risks to operators can be minimized.

A group of people who may be as much at risk as interventional radiologists are radiopharmacists. Under heavy pressure in a busy nuclear medicine department, when handling gigabecquerels of activity a day, they may well act hastily and overexpose their fingers. Measuring the doses to the fingers of such people is very important.

J.H. GÖTHLIN: During over 40 years working in interventional radiology and angiography, from which I have some lesions, I have learned that it is not enough just to have good standards and procedures and good supervision by radiation physicists. From time to time, even the best trained radiologist, nurse or technician may, without realizing it, make a false move, and it may be a long time before it is discovered that he/she has received an excessive radiation exposure. By then, he/she may have, say, cataracts or bone marrow depression. The answer is sensors at sensitive places on the medical worker that will give immediate warning when a false move has given rise to overexposure.

R.P. BRADLEY: I was surprised to learn from J. Barceló Vernet's presentation how little information there was from North America in the OECD summary. I hope there was some information from Canada.

J. BARCELÓ VERNET: Yes, there was. There was no information from the USA, which did not provide any data for inclusion in the UNSCEAR report.

R.P. BRADLEY: Something which is troubling me is the fact that in North America people are more and more frequently having CT scans as a precautionary measure or for cosmetic reasons although there are no clinical symptoms. Clinics are opening up just for that purpose. The phenomenon is perhaps not covered by the regulations, the framers of which did not envisage it. Has it reached Europe yet?

J. BARCELÓ VERNET: In Europe, you cannot simply go and have a CT scan, but the technique is sometimes employed unnecessarily. In my view, there is a need for better training in the prescribing of procedures.

J. LINIECKI: That is more a matter of patient protection than worker protection, which is what we should be focusing on here.

O.W. LINTON: In the field of medical radiology, the dilemma lies not at the centre but at the high-tech edge and the low-tech edge. There has been a strong focus here on the high-tech edge. As to the low-tech edge, where a lot of people are involved, in some countries over half of the people providing X ray diagnosis services have had no training of any significance.

Standards for the radiation protection of medical workers are sorely needed, and the help of the IAEA and ILO will be very welcome.

S.C. PERLE: Regarding what J. Liniecki said about radiopharmacists, ring dosimeters are not enough. If you are not wearing fingertip dosimeters, the dose assessment may be too low by a factor of 5–10.

C.J. HUYSKENS: I agree with O.W. Linton's comment to the effect that the main problems are at the high-tech edge and the low-tech edge.

On the basis of over 15 years of experience, I would say that the mean dose to the individual in a hospital is a useless figure. The ultimate goal of the monitoring of medical workers should be to identify the highly exposed groups, on the one hand by identifying the types of medical practice that involve high doses and, on the other, by identifying poor working procedures and habits.

With regard to the role of the health physicist in, say, the operating theatre, I would say, without much exaggeration, that the health physicist has no role to play there. Health physicists must play their role before their colleagues, the medical specialist, the nurse, the technician, enter the operating theatre.

This means that their colleagues need appropriate education and training in radiation protection before they start applying high risk procedures, for their own benefit and also for the benefit of their patients.

G.A.M. WEBB: In the medical area, we seem not to be stimulating the interest of workers in their own safety. There is a tendency for them not to wear dosimeters, or to wear inappropriate ones. They seem not to realize that, particularly pursuant to the International Basic Safety Standards, they have an obligation to take care of their own protection.

However, I don't know whether anything can be done about that at the international level.

J. LINIECKI: In my view, two of the reasons for the low level of interest of many medical workers in their own safety are poor training in radiation protection and the tremendous pressure under which they are working.

As regards training in radiation protection, the curricula at medical schools are already overloaded, so that such training can only be provided at the postgraduate level. But it must be given and it must lead to rigorous compliance with the radiation safety regulations.

H. RINGERTZ: When I was a hospital resident, physicians used to examine, two or three times a year, the hairs on the backs of the hands of those of us who were working in interventional radiology. If we were losing those hairs, we knew that we had a radiation exposure problem. The psychological effect was stronger than that of dosimeter readings.

T. HEALEY: With regard to the point raised by R.P. Bradley, in the UK there are people offering mammography services without requiring that the clients be referred to them by a physician. In some cases, they park a van in a supermarket car park and provide a ‘walk-in’ service.

In one instance, a physician was producing mammograms with ordinary portable X ray equipment, not special low voltage mammography equipment. He had only one eye; a cataract affecting the other eye. When the matter came to our knowledge, we closed the operation down on technical grounds.

When I was in charge of a diagnostic X ray department and a new physician was not complying with the radiation safety rules, I used to withdraw his/her authorization to prescribe diagnostic examinations. Within 24 hours the physician started complying with the rules.

H. RINGERTZ: The situation in the UK is perhaps worse even than T. Healey imagines. There are already commercial screening units being set up in London.

The only way of combating that trend is to have recourse to the European Union Directive on referral criteria (Council Directive 97/43/Euratom of 30 June 1997 on health protection of individuals against the dangers of ionizing radiation in relation to medical exposure).

C. ARIAS: In the field of occupational radiation protection, it is possible to reduce doses and lower the risk of accidents through good education and training if there is proper enforcement. In some countries, however, it is not clear who is responsible for enforcement — the nuclear regulatory body, the health authorities, physicians, professional societies?

J.H. GÖTHLIN: Good education and training are very important, as is the role of the radiation physicist in surveying the area where the procedures involving ionizing radiation are going to take place. However, despite all the care which is taken, mistakes will occur, and then it is essential that the affected radiation workers know that a mistake has occurred and that they have received excessive radiation.

J. LINIECKI: How does one achieve that?

J.H. GÖTHLIN: By making radiation workers wear, at sensitive places on the body, sensors that will react immediately when the radiation workers are exposed to an excessive dose rate.

S.C. PERLE: In the USA, many interventional radiologists are now wearing, in addition to normal dosimeters, electronic ones that indicate when the doses being received by the wearers are beginning to be on the high side, so that the wearers can adjust their behaviour accordingly. The doses received by those radiologists have been reduced by 10–30%.

With the electronic dosimeters, one can in addition obtain histograms showing exactly when a dose was received. One can then determine what procedure was being carried out at that time and perhaps learn useful lessons.

J. LINIECKI: I believe that, in countries in western Europe, institutions where interventional radiology procedures are being carried out have to have a cumulative dosimeter with a large display which the operator can see. However, such a dosimeter does not react to the dose rate.

C.J. HUYSKENS: Such a dosimeter is not an answer to the problem which J.H. Göthlin outlined. He wants something which will tell him — even make him feel — when, say, his hands are in the radiation beam.

The difficult procedures we are talking about here may well be life saving for the patient and they must therefore not be made even more difficult to perform by overstringent regulation. In the operating theatre, the awareness of the operator, helped by the radiation protection specialist, is crucial.

Regarding G.A.M. Webb's comment about the difficulty of stimulating the interest of medical workers in their own safety, I believe that the difficulty is due partly to the fact that radiation protection in hospitals is often enforced by specialists who have no medical qualifications.

What one needs in hospitals are intelligent solutions, not enforcement by regulations and by 'policemen' telling the operators what the dose levels should be. The radiation protection specialists should not be seen as overrestrictive meddlers, but as people who are there to help.

I have been disappointed by the fact that some people are advocating heavier lead shielding in aprons. In my view, the apron should be as light as reasonably achievable, since it is a burden to the medical worker. Lead shielding 0.3 mm thick is enough for the vast majority of X ray procedures.

M. GUSTAFSSON: Having worked for some 20 years as a physicist responsible for the radiation protection of hospital personnel and patients, I have found this discussion rather depressing; the issues raised here were being raised in the 1970s and 1980s and it seems that we have not moved forward at all. Is that perhaps because there are not enough health physicists working full-time in the diagnostic radiology departments of hospitals? It is not enough for the health physicist to call in at the diagnostic radiology department once a week.

A.S. TSELA: What assistance in the field of occupational radiation protection does the IAEA provide to countries that are not IAEA Member States?

K. MRABIT: Strictly speaking, the IAEA cannot provide assistance to such countries. It does so from time to time, however, if the necessary extrabudgetary funds are made available.

There have been several references to education and training. In that connection, I would mention that, in addition to the postgraduate educational courses which it organizes or sponsors in various regions, the IAEA runs specialized training courses for which it has prepared standardized training packages.

The packages for training in areas such as nuclear medicine, diagnostic radiology and radiotherapy were tested earlier this year. Early next year, they will be translated from English into other official languages of the IAEA, after which they will be disseminated to regional education and training centres and provided to IAEA Member States on request.

OCCUPATIONAL RADIATION PROTECTION IN WORKPLACES INVOLVING EXPOSURE TO NATURAL RADIATION

(Topical Session 6)

Chairperson

K. ULBAK
Denmark

OCCUPATIONAL RADIATION PROTECTION IN WORKPLACES INVOLVING EXPOSURE TO NATURAL RADIATION

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Abstract

For natural radiation, occupational radiation protection in workplaces involves the protection of workers against enhanced exposures due to cosmic and terrestrial radiation, the latter due to human activities. Enhancement is measured against an uncertain level of background radiation at an estimated average global per caput dose of 2.4 $mSv \cdot a^{-1}$. For cosmic radiation, enhanced exposures mainly arise from flying in aircraft. For occasional and frequent flyers this generally measures below 1 $mSv \cdot a^{-1}$. For aircrew, doses within the range 2.5–4.0 $mSv \cdot a^{-1}$ are, however, reported. Enhanced terrestrial radiation is mainly associated with mining and minerals processing operations. For mining, ore processing and physical separation process facilities, ^{238}U or ^{232}Th concentrations within the range 1–14 $Bq \cdot g^{-1}$ could typically result in an external radiation or dust inhalation dose of 1 $mSv \cdot a^{-1}$ (2000 h). For chemical extraction and metal melting plants the relation is more variable. Values within the range of 0.1–10 000 $Bq \cdot g^{-1}$ have been reported for various industries. Regulatory aspects for occupational exposure to natural radiation are briefly introduced. Some of the more pronounced differences between occupational exposure due to naturally occurring radioactive material and that due to the nuclear industry are briefly indicated, with some of the remaining problem areas discussed.

1. INTRODUCTION

Natural radiation refers to ionizing radiation, originating either from high energy cosmic rays entering the earth's atmosphere from outer space or from naturally occurring radioactive materials (NORM) present in the crust of the earth. This radiation is distinguished from artificial radiation produced through human-made nuclear or atomic transformations.

The exposure of human beings to a background of natural radiation is a continuing and inescapable feature of life on earth. The background exposure level in the earth's biosphere varies both with space and time, roughly within the range of 1–10 $mSv \cdot a^{-1}$, with an estimated global per caput average of 2.4 $mSv \cdot a^{-1}$ [1]. In the case of natural radiation, occupational radiation protection involves the control of enhanced exposures to natural radiation in workplaces and that caused by human activities. Variations in background exposure levels cause some uncertainty when determining the level of enhancement within the range of the background levels.

This paper provides a discussion on various sources of enhanced occupational exposure to natural radiation, including typical exposure pathways and levels of exposure. Some IAEA guidance on the control of these exposures is summarized next. Finally, general remarks on the exposure levels and their control are provided with suggestions on problems requiring further investigation.

2. COSMIC RADIATION

When entering the atmosphere, cosmic rays interact with nuclei of the atmosphere, producing a complex nucleonic cascade of charged and uncharged primary and secondary particles. Although the relative contribution of various particles to the exposure level varies with altitude, the overall level generally decreases with depth of penetration into the atmosphere. The protons (as the main primary component entering the atmosphere) are also affected by the earth's magnetic field, causing a latitude effect with higher levels of radiation occurring near the poles of the earth than at the low latitudes near the equator. Finally, the cosmic radiation level shows a temporal variation, where a significant decrease in levels has been noted with increasing solar activity [2].

Although the complex nature of the particles causes some uncertainty in dose assessments, the average per caput effective dose from cosmic rays has been estimated at 380 $\mu Sv \cdot a^{-1}$ [1, 3]. As most people live at low latitudes, the geomagnetic latitude effect on this result is estimated to be only 10%, with another 10% due to variation in solar activity [1]. At ground level, cosmic radiation is normally regarded as background irrespective of the altitude or latitude. Cosmic radiation levels in deep underground mines are again significantly less than those at ground level.

Enhanced occupational exposure to cosmic radiation occurs during high altitude flights. Extensive monitoring on such flights by the European Commission [2] produced the results in Fig.1. Variations due to altitude, latitude and solar activity are indicated in the Fig. 1.

Subsonic aircraft normally travel at an altitude of 9–12 km, where dose rates at temperate latitudes are in the range of 5–8 $\mu Sv \cdot h^{-1}$, as opposed to only 2–4 $\mu Sv \cdot h^{-1}$ at equatorial latitudes. The route dose for a transatlantic flight from Europe to North America will typically be 30–45 μSv, while the route dose from Europe to Johannesburg may only be around 25 μSv [2]. Typical average annual dose ranges for different categories of passenger and crew at temperate latitudes in subsonic aircraft are indicated in Table I [1]. For lower latitudes the average annual dose ranges will be less by a factor of around two.

Only a small proportion of passengers and crew fly in supersonic aircraft at higher altitudes (~18 km) and these are subject to dose rates of 10–12 $\mu Sv \cdot h^{-1}$ [4]. At

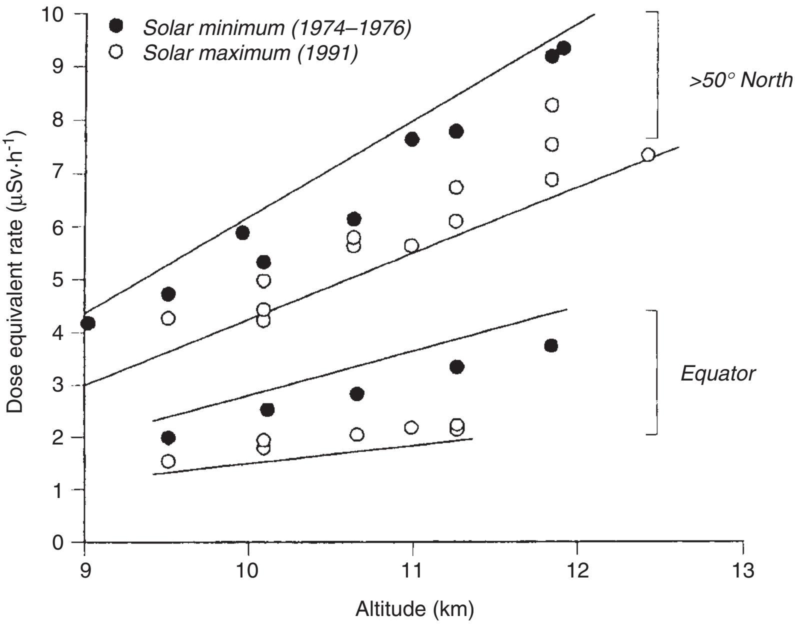

FIG. 1. Cosmic ray exposures as a function of aircraft altitude, latitude and solar activity.

these altitudes solar particle events may even cause higher dose rates [1], although these events are very rare and their effect, on average, insignificant.

Interactions of cosmic radiation with atmospheric nuclei generate cosmogenic radionuclides in the atmosphere and these may be inhaled. The occupational radiation risk from these, however, is insignificant.

TABLE I. CATEGORIES OF SUBSONIC AIRCRAFT FLYER AND ASSOCIATED ANNUAL DOSES AT TEMPERATE LATITUDES

Flyer category	Flying period range ($h \cdot a^{-1}$)	Average flying period ($h \cdot a^{-1}$)	Average dose range ($\mu Sv \cdot a^{-1}$)
Occasional flyers	3–50	10	50–80
Frequent flyers	50–1200	100	500–800
Crew	300–900	500	2500–4000

3. TERRESTRIAL RADIATION

Terrestrial radiation originates from primordial radionuclides such as uranium, thorium and potassium in the crust of the earth. Median ranges of 16–110 $Bq{\cdot}kg^{-1}$ and 11–64 $Bq{\cdot}kg^{-1}$ for ^{238}U and ^{232}Th respectively have been reported for soil, with population weighted means of 33 $Bq{\cdot}kg^{-1}$ and 45 $Bq{\cdot}kg^{-1}$ respectively [1]. Elevated levels of these materials should hence be seen against the mean values and the ranges noted above. Occupational exposure to elevated levels of terrestrial radiation mainly occurs within the mining and minerals processing industries, including some downstream processes. Enhancement can either be due to elevated levels of radioactivity in the ore or the mineral itself, or sometimes also to enhanced exposure periods or to conditions in the working environment.

Although some minerals such as rare earths, phosphates, mineral sand products and mineral oil are more closely associated with NORM, all ores can contain elevated levels of natural radioactivity. The level of enhancement during the mining and initial ore processing operations is often unrelated to the metallurgical process to be applied subsequently and may well be dealt with separately. For these processes, the radionuclides in each of the uranium and thorium decay chains will stay more or less in secular equilibrium.

A summary of the more important occupational exposure pathways for mining and ore processing operations is indicated below with approximate exposure levels.

3.1. Mining and ore processing

Exposure levels during mining increase with the uranium and thorium ore grade for all pathways and for all mining methods. Approximate external radiation doses are estimated in Table II from published dose coefficients [5]. The results indicate that a dose of 1 $mSv{\cdot}a^{-1}$ (for the maximum occupational exposure period of 2000 $h{\cdot}a^{-1}$) is only possible for ore with 114 ppm uranium or 250 ppm thorium. This relates to ^{238}U and ^{232}Th activity concentrations of about 1.4 $Bq{\cdot}g^{-1}$ and 1.0 $Bq{\cdot}g^{-1}$ respectively. At ore grades above 2200 ppm uranium (27 Bq $^{238}U{\cdot}g^{-1}$) or 5000 ppm thorium (20 Bq $^{232}Th{\cdot}g^{-1}$), doses could exceed annual dose limits for workers at the maximum exposure period. In terms of optimization requirements, some shielding or other controls will need to be provided at some concentration below the latter values. For shorter exposure periods, the reference concentrations will be proportionally higher.

A general rule for estimating dust inhalation doses is more difficult as dust levels are greatly influenced by operational conditions. The dose may, however, be conveniently related to the gravimetric concentration of airborne dust, assuming this to have an activity median aerodynamic diameter of 5 μm. The nuclides in the airborne dust are sometimes concentrated relative to those in the bulk material, typically by a factor of between one and two, but up to around ten in the dry circuits

TABLE II. REFERENCE CONCENTRATIONS FOR ORES AND CHEMICALLY UNALTERED BULK MATERIALS

Dose coefficients and reference concentrations for external radiation doses

Source description	Dose coefficient ($nSv \cdot h^{-1}$ per ppm)		Reference concentration (ppm for 1 $mSv \cdot a^{-1}$)		Reference concentration ($Bq \cdot g^{-1}$ for 1 $mSv \cdot a^{-1}$)	
	U	Th	U	Th	U-238	Th-232
Infinite slab	4.4	2.0	114	250	1.4	1.0
Large pile	2.6	1.2	189	417	2.3	1.7
Small pile or large process equipment	1.3	0.6	379	833	4.7	3.4
Small process equipment	0.4	0.2	1136	2500	14	10

Dose coefficients and reference concentrations for dust inhalation doses

Dust load ($mg \cdot m^{-3}$)	Airborne concentration factor	Dose coefficient ($nSv \cdot h^{-1}$ per $mg \cdot m^{-3}$ per ppm in bulk material)		Reference concentration in bulk material (ppm for 1 $mSv \cdot a^{-1}$)		Reference concentration in bulk material ($Bq \cdot g^{-1}$ for 1 $mSv \cdot a^{-1}$)	
		U	Th	U	Th	U-238	Th-232
1	1	0.43	0.23	1163	2174	14.4	8.8
1	2	0.86	0.46	581	1087	7.2	4.4
5	2	0.86	0.46	116	217	1.4	0.9
5	10	4.3	2.3	23	43	0.29	0.18

of mineral sands operations. Given the assumptions made above, approximate dust inhalation doses are estimated in the lower section of Table II from published inhalation dose coefficients [6] for bulk materials with all radionuclides in each of the uranium and thorium series in equilibrium. For a dust load of 1–5 $mg \cdot m^{-3}$ and an airborne concentration factor of two, a dose of 1 $mSv \cdot a^{-1}$ will in this case relate to generally higher ^{238}U and ^{232}Th activity concentrations of around 1–7 and 1–4 $Bq \cdot g^{-1}$ respectively.

The results indicate that inhalation doses may become similar to external doses for infinite slab sources only at an unlikely high gravimetric dust load of 5 $mg \cdot m^{-3}$ and an airborne concentration factor of two. External doses are hence likely to dominate in mining areas and near large piles of process material. For small piles and process equipment, external doses would be reduced by smaller geometry factors as indicated in Table II. This would likely cause the dust inhalation pathway to become dominant in ore processing areas.

Owing to the low dissolution rate of ore, dust ingestion is normally of much lesser radiological concern than are external radiation and dust inhalation.

Estimation of radon and thoron inhalation doses from the ore grades is almost impossible without detailed modelling. These levels are not only extremely dependent on the ventilation conditions within a workplace, but also on the exhalation rate from emanating surfaces. This again depends both on the emanation characteristics, determined by the crystal structure of the grains of the matrix material, and on the diffusion characteristics of the matrix material, mainly determined by the intergrain porosity. Exposure levels or gas concentrations of radon and thoron should hence rather be measured in underground and other poorly ventilated areas. The gas concentrations can only be related to a dose if the equilibrium factor, *F*, between the gas and the short lived progeny is known. The relations of $8.0 \times F$ $nSv \cdot h^{-1}$ per $Bq \cdot m^{-3}$ for radon and $36 \times F$ $nSv \cdot h^{-1}$ per $Bq \cdot m^{-3}$ for thoron are deduced from data in Refs [1, 7]. Despite the larger conversion coefficient, the risk from thoron can mostly be disregarded when compared with that from radon, except when ^{224}Ra concentrations are considerably higher than ^{226}Ra concentrations.

In opencast mines the radon risk is generally lower than that from external radiation but may be comparable to that from dust inhalation. It often dominates, however, in underground mines. While concentrations in well-ventilated underground areas are normally at levels well below the annual occupational dose limit, concentrations associated with doses well above this limit are common to areas of poorer ventilation. Igneous rock normally 'exhales' smaller amounts of radon than sedimentary rock, often causing lower levels in mines in the former type of rock. In open ore processing areas, doses from radon should still be lower than those received from external radiation and dust, but could increase inside buildings owing to poorer ventilation. The effect of natural radioactivity in the building material and elevated levels in subfloor areas may also affect indoor levels.

Present guidance from the International Commission on Radiological Protection and the IAEA is that, where radon is incidental to mining or mineral processing operations, the requirement for its control is determined by an action level of around 500–1500 $Bq \cdot m^{-3}$ (relating to a dose of 3–6 $mSv \cdot a^{-1}$) [7, 8]. It would, however be difficult to relate this to a ^{226}Ra or uranium concentration range. One motive behind the use of this action level may be the fact that many people are exposed to background radon levels in the low $mSv \cdot a^{-1}$ range.

3.2. Extraction and downstream processes

The general approach, which is based on the ore grade, as presented above, often breaks down in the extraction sections of processing plants when these cause

TABLE III. REFERENCE LEVELS FOR NORM INDUSTRIES[a]

Material/process	Nuclide (Bq·g^{-1} resulting in 1 mSv·a^{-1} under normal assumptions)					
	Th-232	Th-228	U-238	Th-230	Ra-226	Pb/Po-210
			Phosphate industry			
Mining and milling of phosphate ore	10	4	80	20	0.5	200–300
Wet processing of phosphate ore	10	5	80	20	1	200–300
Thermal processing of phosphate ore	10	5	80	20	4	200–300
General fertilizer	10	5	80	20	1	200–300
			Ferro-niobium industry			
Pyrochlore feedstock	10	3	80	20	0.1	200–300
			Tin smelting			
Tin smelting slag	10	5	80	20	3	200–300
			Zircon industry			
Zircon sands	7	4	40	9	1	100–200
Refractory products	30	30	200	50	30	600–900
			Rare earth extraction			
Monazite/bastnanite sand	10	6	80	20	0.8	200–300
			Thorium products industry			
W–Th welding rods	300	300		300		
Gas mantle storage	10^6	700		10^6	600	10^5–10^8
			Titanium dioxide industry			
Ilmenite feedstock	10	4	80	20	0.6	200–300
			Oil and gas extraction			
Radium scales in pipes	100	60			60	
Removal of sludges	100	10			20	
			General metal melting			
Pb/Po precipitate						400–1000
Volatilized Pb/Po						400–10 000

[a] Source: Radiation Protection No. 95 (see Ref. [9]).

changes in the relative nuclide composition of the process materials. The European Commission has completed a comprehensive study to determine reference levels for many industrial (NORM) processes [9]. This study mainly covered downstream processes, but it also included some processes sometimes performed at similar primary mineral extraction plants or operations. The technical basis for the study is also presented in detail in Ref. [10]. Resultant indicator levels are provided as the approximate activity concentrations of the ^{238}U, ^{235}U and ^{232}Th parent nuclides related to different annual doses. More detailed reference levels for all longer lived nuclides are also presented. Indicator and reference levels are provided for normal as well as conservative, but unlikely, conditions. A summary of the more relevant reference levels is presented in Table III. Radon inhalation was included as a pathway in these dose assessments, rather than handling it in terms of an action level as mentioned in Section 3.1. This causes ^{226}Ra to be the critical nuclide in many of the cases. A lower reference level for ^{226}Ra in zircon is in fact proposed mainly by using a measured but much lower radon emanation coefficient for zircon sands [11]. Radon-226 is also critical in terms of external radiation, but closer to the value of ^{228}Th; with an almost similar external dose coefficient.

A few additional remarks may be relevant to extraction processes.

3.2.1. Physical extraction processes

Physical extraction processes include gravity concentration as well as electrostatic and magnetic separation processes often used to extract or separate heavy minerals. It also includes flotation processes used to extract minerals such as phosphate rock, copper sulphides, pyrites and other minerals. Although these processes may cause a considerable increase in the radionuclide concentrations of process materials, including products and/or waste streams, the relative abundance of the different radionuclides in each of the uranium and thorium decay chains is not altered appreciably, as long as the process occurs in a chemically neutral environment. Only the uranium and thorium concentrations in these materials therefore need to be determined to allow approximate dose assessments to be made as per the methods presented in Section 3.1.

Using a geometry factor of 0.1 as suggested in Table II for small sources, and a dust concentration of 1 $mg \cdot m^{-3}$, a dose rate of 1 $mSv \cdot a^{-1}$ may only be exceeded when the uranium and thorium concentrations exceed 7 and 4 $Bq \cdot g^{-1}$ respectively, as determined by the dust inhalation pathway.

While radionuclide concentrations vary among deposits, typical concentration ranges (in ppm) for the ore, process materials and products within the mineral sands industries of the major producing countries are indicated in Table IV.

Application of the mid-values of the ranges in Table IV to the relations described in Section 3.1 demonstrates that large piles of material containing more

TABLE IV. TYPICAL NUCLIDE CONCENTRATIONS (PPM) OF MINERAL SAND ORE, PROCESS MATERIAL AND PRODUCTS

Process material/mineral	Nuclide concentration (ppm)	
	U	Th
Ore	3–9	5–45
Heavy mineral concentrates	10–50	80–180
Ilmenite	10–50	10–100
Leucoxene	20–100	50–250
Rutile	10–40	20–70
Zircon	150–360	100–160
Monazite	1000–3000	50 000–70 000

than around 50% zircon or 0.4% monazite have the potential to expose workers to external doses above 1 $mSv{\cdot}a^{-1}$, but that smaller piles do not.

Comparison of the uranium and thorium concentrations of the non-magnetic feed material with those of the baghouse dust of mineral separation plants indicated an increase by a factor of around ten in these concentrations in the airborne dust of dry circuits. This is five times higher than the concentration factor of two assumed in Section 3.1. This concentration increase will cause dust inhalation doses to exceed the 1 $mSv{\cdot}a^{-1}$ level already due to dust loads of around 1 $mg{\cdot}m^{-3}$ if the non-magnetic feed to the plant contains 0.4% monazite. Dust loads in these plants are generally above 1 $mg{\cdot}m^{-3}$ and doses in the dry circuits of mineral separation plants are in fact generally within the range of 1–5 $mSv{\cdot}a^{-1}$ or even higher for ore bodies with higher monazite contents.

3.2.2. Chemical extraction processes

Chemical extraction processes can cause large increases in the concentrations of NORM in the product, process or waste streams, largely dominating variations in the activity concentration of the ore. While some chemical reactions, such as the cyanide leaching of gold, have very little effect on radionuclide concentration, leaching with strong alkalis or acids (e.g. uranium and rare earth extraction processes and sulphuric and phosphoric acid production) normally causes large changes in nuclide concentration. Dissolved radionuclides can again precipitate when chemical conditions change, generating scales on the walls of vessels and pipes. Precipitates and scales can cause relatively high levels of both external, inhalation as well as ingestion doses, but should, rather, be assessed on a case by case basis as in Ref. [10]. Similar scales can also be generated in mining and ore processing facilities as a result of geochemical reactions, for example, the oxidation of pyritic ores, but the levels are generally much lower. Precipitation may also be enhanced by pressure and temperature changes, for example, in the oil and gas industry when vapours in hot gases are depressurized or cooled as a result of being brought to the surface from underground wells.

Metal melting as a chemical process may also enhance radioactive concentrations present, for example, as volatile ^{210}Pb and ^{210}Po in the flue gas which condense again in stacks or scrubbers, thereby posing as dust inhalation hazards during maintenance operations. Relatively high reference levels apply to these, however, as shown in Table III.

4. REGULATORY ASPECTS

As regards exposure to elevated levels of cosmic radiation, no formal IAEA regulatory guidelines for occupational exposure have been formulated.

Regulatory aspects of occupational exposures to NORM are presently under review. A forthcoming IAEA publication is expected to address these with respect to the mining and processing of, and exploration for, uranium and thorium ores, as well as other operations involving raw materials containing NORM. The proposed approach distinguishes between four categories of materials as indicated below:

(a) Uranium and thorium ores mined for their uranium and thorium contents.
(b) Other radioactive ores (including ores from which uranium and thorium are extracted as by-products). Examples of this category include some mineral sands containing monazite, rutile and zircon (e.g. from a point where the monazite concentration exceeds some specified value), and some phosphogypsum mining operations.
(c) Raw materials that are not radioactive ores but where occupational radiation protection measures are required to deal with exposures arising adventitiously in the workplace environment. Examples include gold mines where radon levels are high.
(d) Other raw materials.

While the stringency of control should decrease from the first to the last category, regulation through a nuclear licence is proposed for the first two categories of operations. Registration is regarded as the possible regulatory mechanism for the third category, except when exposures are high (e.g. when radon concentrations in workplaces are above the average action level of 1000 $Bq \cdot m^{-3}$, or when nuclide concentrations in the airborne dust exceed some level within the range of 1–10 $Bq \cdot g^{-1}$). The last category covers operations which may qualify for exemption. More detail is, however, required on the application of action levels as this may result in some irrational differences between the regulation of licensed and non-licensed practices.

The IAEA publication is expected to discuss how regulatory requirements should be fulfilled and responsibilities discharged, the applicable dose limits, the requirements of an occupational radiation protection programme, the application of engineering and administrative protection measures, and health surveillance requirements. These are, however, to a large extent similar to regulatory requirements for the non-NORM industry. The main differences are explained in a slightly more detailed discussion on engineering and administrative control measures in Section 5.

5. ENGINEERING AND ADMINISTRATIVE CONTROL

Occupational exposures to NORM are generally at much lower levels than in the nuclear industry. Owing to the fact that more workers are exposed, the collective exposure may, however, be higher rather than lower. The overall requirement for control may hence not differ substantially but would, rather, focus on low level rather than high level exposures (e.g. less emphasis on defence-in-depth and low frequency, high risk probabilistic events).

Except where ores with relatively higher uranium and thorium grades are involved (approximately above 500 and 1000 ppm respectively), annual occupational doses in modern NORM processing facilities should in most cases not exceed 5 $mSv \cdot a^{-1}$. This is within the range requiring a continuous review of the exposures on the basis of area monitoring results, rather than on individual monitoring of workers. Otherwise, the monitoring of a statistically representative subset of workers may be sufficient. Generally, expensive engineering solutions aimed specifically at reducing radiation risks would also not be required to the same degree as in the nuclear industry. As regards cost, this situation compensates to a large extent for the larger number of workers in the NORM industry and especially those in underground mining areas.

Monitoring would mostly involve external gamma dosimetry by either hand-held survey meters, or by thermoluminescent or electronic dosimeters, and air sampling using personal air samplers for both area and individual measurements. Control would mostly be administrative through the wearing of protective clothing, including gloves, and the wearing of respirators in areas where dust levels or dust activity concentrations are high.

A notable exception is the presence of radon in large underground areas of some mines, where doses may not only be high, but where large spatial and temporal variations in both gas concentration and equilibrium factors may occur. The large numbers of workers may, from a cost perspective, preclude the use of personal radon exposure monitors. Engineering control through increased ventilation is also in many cases a very costly exercise. Cost effective solutions to these problems need to be further investigated. Other exceptions would be surface plants with high chemical enhancements of radioactivity and dry heavy mineral circuits with high dust levels. Fewer workers are, however, present in these plants.

Ore grades above the level indicated previously may in many cases relate to uranium mines or to the extraction of rare earths or other elements from monazite and where licensed regulation would be required. More expensive engineering measures such as shielding and remote control may also be required for some of these operations.

6. SUMMARY AND CONCLUSIONS

This paper presents data on the exposure of aircrew and flyers during flights. It also presents data correlating the possible dose with the activity concentrations of ores during mining and NORM processing operations and identifies mineral processes for which such a correlation becomes difficult. A general overview of assessment aspects of occupational radiation protection within the NORM industry is presented.

While approximate dose assessment methodologies seem rather easy for external radiation and dust inhalation within mining, ore processing and even some physical mineral extraction operations, radon exposures and chemical extraction methods require rather more specific evaluations. A summary of data from studies, particularly on downstream processes, is presented. These studies should also be extended to cover the primary extraction processes.

Finally, it is indicated that the monitoring and control of larger numbers of workers in the NORM industry are largely compensated for by less stringent monitoring and control requirements at the lower dose levels. Exceptions are radon in large underground mining areas and operations on ore containing higher levels of uranium or thorium or operations chemically enhancing radionuclides to high concentrations.

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RAPPORTEUR SUMMARY

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1. INTRODUCTION

It has been well known for a considerable period of time now that natural radiation is the major source of exposure to humans. Sources of natural radiation are ubiquitous. Natural uranium and thorium, together with their decay products, and ^{40}K are present in the earth's crust and water bodies. Cosmic radiations of galactic and solar origin continuously enter the atmosphere. While we are continuously exposed to internal and external radiations to varying degrees, depending on the geological settings, human activities such as aviation, the mining and processing of minerals (both radioactive and non-radioactive) and the production of oil and phosphatic fertilizers, as well as the natural occurrence of radon in dwellings and workplaces, all cause additional exposures. A large body of literature exists on the subject. Sources of natural radiation of terrestrial and cosmic origins and those enhanced by human activities such as the mining and processing of raw materials, with their relative contributions, have been very well documented in a series of reports of the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) for 1977, 1982, 1988, 1993 and 2000.

In this session there are fourteen contributed papers dealing with exposure to natural radiation occurring during diverse human activities ranging from aviation to confined or subsurface workplaces, oil exploration and production, mining and processing of raw materials. These may be broadly divided into four subject areas.

Two papers deal with the concept for control and optimization; six papers discuss naturally occurring radioactive materials (NORM) and technologically enhanced naturally occurring radioactive materials (TENORM) (dealing with the aviation industry, the oil exploration and production industry and the processing of non-radioactive raw materials); three papers deal with dwellings, confined and subsurface workplaces; and three papers discuss the mining industry (coal and uranium).

2. CONCEPT FOR CONTROL AND OPTIMIZATION

Two papers deal with the concept for control of occupational exposure and optimization of internal exposure of workers arising from natural sources of radiation. The International Basic Safety Standards (BSS) and the Council of the European Union Directive 96/29 require that Member States identify and include under institutional control such human activities or practices that lead to the significant radiation exposure of workers and members of the public. Practices often result in an increase in exposure to natural radiation. Hence, work should be planned such that exposures are under institutional control and the limits not exceeded. Justification of a practice, optimization and dose limitation are the guiding principles for control of the radiation exposure of workers and members of the public.

A system of exemption and clearance is suggested to exclude from institutional control such natural activities and materials that lead to very low levels of exposure and which pose negligible risks. However, these exemption levels must be used with caution. For example, the exemption level of 10 μSv/a will be exceeded at workplaces in many areas of the world and, as such, a large number of practices will come under the purview of institutional control involving high and unjustifiable costs. It is, however, recognized that radionuclides in the human body, cosmic radiation at ground level and radionuclides in the undisturbed earth's crust are not amenable to control. Hence, institutional control is justified only for sources that are amenable to control.

Radon in workplaces is an important source of exposure to natural radiation and it is, to a great extent, amenable to control. It is emphasized that for all work areas the exposure must be estimated. Exposure levels exceeding 2×10^6 $Bq \cdot h^{-1} \cdot m^{-3}$ necessitate remedial measures. If exposures cannot be reduced below this level then the workers have to be monitored.

Between 5000 and 10 000 workers are potentially exposed to internal radiation in different industries in the European Union (EU). A project has been initiated to recommend monitoring strategies and methods for the optimization of internal exposures. Results of these studies will be utilized for implementation of the 'as low as reasonably achievable' principle.

3. NORM AND TENORM

3.1. Aviation industry

The aviation industry worldwide employs a large number of workers. About 50% of the transport aircraft crew consists of females. The flight crew is occupationally exposed to cosmic radiations that increase with the altitude and latitude. They are among the highly radiation exposed occupational groups in the United States of America. The International Commission on Radiological Protection (ICRP) Publication 60 (1990) recommendation that exposure to cosmic radiation at high altitudes be considered as occupational exposure, when appropriate, has been adopted in EU and Czech Republic regulations since 1996 and 1997, respectively, though not yet in US regulations.

The EU Directive requires that doses for aircraft crew likely to receive above 1 mSv/a be evaluated and regulated. For this purpose four protection measures are identified: (i) assessment of the exposure of the aircraft crew concerned, (ii) consideration of the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed aircrew, (iii) informing the workers of the health risks involved, and (iv) provision of the same special protection to female aircrew during pregnancy as that provided to other female radiation workers.

These measures are being incorporated into laws and regulations and are being included in the aviation safety standards and procedures. The preferred approach, supported by guidance from ICRP Publication 75, is that where the assessment of the occupational exposure of aircraft crew is necessary, doses can be computed from staff roster information, flight profiles and calculations of cosmic radiation dose rates as a function of altitude, geomagnetic latitude and solar activity. The calculations should be periodically validated by measurements.

3.1.1 Exposure estimates

In the Czech study, the aircrew exposure estimates were initially made using the code CARI version 3N, developed in the USA, which incorporates flight altitude, optimum and constant times for take-off and landing, flight time and solar activity, etc. The data analysis of over 3000 flights during 1998 indicated an overestimate of about 10% from the measurement results.

The EU study uses different types of passive and active dosimeter aboard aircraft to evaluate absorbed dose or dose equivalent for cosmic radiations. Route dose calculations are performed using codes such as CARI or EPCARD. The agreement between data obtained experimentally and those from the codes is within 20%. A current DOSMAX project involving over 10 laboratories is studying different dosimetry aspects of the aviation industry in detail.

The US study used two simultaneously operating tissue equivalent proportional counters, each calibrated with a ^{137}Cs source for low linear energy transfer (LET) and an Am/Be source for the high LET component. Radiation doses were also estimated using the most recent computer model CARI version 4 Q. The model takes into account altitude changes and geographical location from take-off to touchdown, geomagnetic shielding and the solar cycle stage at the time of the flight. Input variables include origin and destination cities, flight duration, flight date, number and height of cruising altitudes, and ascent and descent times.

The dose results reported in these studies, summarized in Table I, vary widely depending on the type of aircraft, flight altitude, route travelled, etc. However, as the exposure rates are significantly above the normal background levels and doses are sometimes above the public dose limit of 1 mSv/a, the studies underline the need to regulate occupational dose for flight crews all over the world.

TABLE I. AVIATION INDUSTRY STUDY DATA

Study/parameter	Value
Czech study	
Exposure rate:	<0.2–5.5 μSv/h (2.5–4.0 μSv/h, ~70% of values fall in this range)
Average annual effective dose rate:	~2.0 mSv/a
Dose rate for short haul flights in Europe:	1.6–2.0 mSv/a (~60% of values fall in this range)
Dose rate distribution for long haul flights to North America show two maxima:	1.6–1.8 and 1.8–2.0 mSv/a (~32% of these values fall in each of these ranges)
EU study	
Ambient dose equivalent at temperate latitudes (40–60°) by different groups at 10 km altitude:	
Neutron dose rate:	2.8–8.5 μSv/h (5.6–17.0 mSv/a)[a]
Total dose rate:	4.7–12.7 μSv/h (9.4–25.4 mSv/a)[a]
US study	
Dose equivalent range:	0.69–65.4 μSv per flight of 49–851 min duration (0.84–4.6 μSv/h)
Annual dose rate:	0.2–5.0 mSv/a
Dose for long haul flight (New York–Hong Kong):	90 μSv per flight

[a] Computed for 2000 h/a.

3.2. Oil exploration and production industry

Waste products from oil and natural gas exploration and production are associated with natural radioactivity of ^{226}Ra, ^{228}Ra and ^{210}Po from ^{238}U and ^{232}Th series and ^{40}K in widely varying concentrations. These are initially present in the geological structures and become redistributed in the processes of mining and treatment in the form of scales and sludge which contaminate the equipment surfaces and become a source of radiation exposure to workers. The disposals of residues have a significant environmental and public exposure potential, necessitating the radiation protection of workers, the environment and members of the public.

One paper mentions that a document has been developed in the Russian Federation which contains requirements for the organization and management of radiation control at all stages of waste products handling in the oil and natural gas industry.

Classification of waste products is based on effective specific activity of the natural radionuclides present, according to the relation, $A_{eff} = A_{Ra\text{-}226} + 1.3\, kA_{Ra\text{-}228} + 0.09\, A_{K\text{-}40}$ (Bq/kg) with k values given for different ages of the waste. Depending on the A_{eff} and the gamma radiation dose rate at 0.1 m, the wastes are classified into categories I, II and III.

Similarly, radiation exposure limits for workers and members of the public are prescribed as 5 mSv/a and 0.1 mSv/a, respectively. The criteria for decommissioning of the site are set such that the gamma radiation dose rate does not exceed 0.2 μSv/h, the effective specific activity of soil and rock is not above 370 Bq/kg and that natural radionuclides in the water of open reservoirs are not above twice the initial value.

In the Brazilian oil and natural gas industry, the measurement of radiation levels, radioactivity in scales and sludges and ^{222}Rn levels has been performed in offshore and onshore facilities.

Gamma radiation levels varying from 0.2 to 2.0 μSv/h in warehouses and up to 300 μSv/h near a barrel of oil have been observed. Radium-226 and ^{228}Ra activities in scales from offshore production tubes have been found to be 5587 Bq/g and 7745 Bq/g, respectively. The average activity concentration in sludge was found to be 184 Bq/g with a maximum value of 578 Bq/g. It was further observed that ^{226}Ra activity was higher than that of ^{228}Ra. Radiation levels at offshore locations are generally around 0.2 μSv/h but values as high as 1.0 μSv/h are also observed.

Of the nearly 20 000 workers employed in the Brazilian oil and natural gas industry about 3000 work on platforms.

Considering the large number of workers employed and the significant radiation and radioactivity levels observed, reference levels have been set and an occupational radiation protection programme has been suggested for the industry.

3.3. Processing of non-radioactive raw materials

Using the BSS as the basis, the Indonesian regulatory authority, in common with its counterparts elsewhere, prescribes exemption levels for activity concentrations, total activity and dose rates for operational practices that do not require licensing. A preliminary assessment of radioactivity concentrations and dose rates in some materials from the phosphate, tin and oil industries shows that concentrations of ^{238}U, ^{232}Th, ^{226}Ra and ^{228}Ra vary over a wide range. A large number of the measurements show activity concentrations far in excess of the exemption levels of 1 and 10 Bq/g for ^{232}Th and ^{226}Ra, respectively. Scales and sands from the oil industry show the highest levels of ^{226}Ra and ^{228}Ra. Similarly, external dose rates in tin mining and the oil industry show levels of 1.1–5.2 mSv/a and 1–40 mSv/a, respectively. These are above the dose limit of 1 mSv/a for the public and several orders of magnitude higher with respect to the exemption level of 10 μSv/a. Similar situations have been reported by UNSCEAR (2000).

This leads to a complex situation. Either these industries have to be brought under the same level of regulatory control as that of the nuclear industry or else the radiation safety standards for TENORM should be treated differently. While the first option will require a much larger infrastructure to enable the regulatory authority to investigate all practices with the potential for radiation exposure, the second option will imply that radiation exposure from TENORM has a lower risk than that from the nuclear industry. This indicates that the BSS exemption levels need in-depth study before their straightforward application. This is a situation that prevails in many countries.

4. DWELLINGS, CONFINED AND SUBSURFACE WORKPLACES

4.1. Indoor radon

Indoor ^{222}Rn with its progeny is known to be a major source of natural radiation exposure. Everyone, whether working or not, is exposed to some degree of radiation from radon. Soils, rocks and construction materials emit gamma radiation and radon, causing the exposure of workers and the public at large.

Indoor radon measurements in the coastal and Rift valley regions of Kenya using electrets showed wide variation in indoor concentrations. The coastal regions of Taita and Tavet have relatively cold climates and the mud brick houses showed higher indoor radon values averaging around 278 and 240 Bq/m^3, with corresponding annual doses in the range of 3.0–3.6 and 2.5–3.1 mSv/a, respectively. The warm Soi regions of the Rift valley (24–32°C) showed somewhat lower indoor radon concentrations, averaging 67 and 199 Bq/m^3 for mud brick and stone houses, respectively. These correspond to doses of 0.7–0.9 and 2.1–2.6 mSv/a. Similarly, the Okaria region with concrete houses and wooden houses showed relatively lower average radon levels of 37 and 60 Bq/m^3, respectively, accounting for doses of 0.4–0.5 and 0.6–0.8 mSv/a, respectively.

It is brought out in this paper that affluent people with compact stone houses and offices in fluorspar mining areas in Kenya incur relatively higher radiation exposure. As women spend more time indoors, it is they who are likely to incur relatively higher exposures.

Exposure to radon in enclosed workplaces such as a reactor building is another example. In different work areas of the 'RA' research reactor in Yugoslavia, a one-year study of microclimatic parameters of temperature, relative humidity and air velocity was carried out along with that of indoor radon using CR-39 solid state nuclear track detectors. The temperatures ranged from 11.6 to 21.9°C, relative humidity ranged from 30% to 75%, while the air velocity varied between 0.04 and 0.17 m/s. The comfort zone criteria of air velocity and a temperature range of 17.2 to 21.2°C were partially or fully met in some parts of the reactor building.

The radon (^{222}Rn) concentrations measured in the eight work zones varied from 44 to 976 Bq/m^3. The higher values of 899 and 976 Bq/m^3 were obtained in the summer. The lower values of 44 and 46 Bq/m^3 were observed in spring and winter, respectively. The estimated average doses from radon in different zones varied from 0.4 to 1.64 mSv/a. The collective annual occupational dose due to radon was 68.8 man·mSv.

The external dose rate observed was 0.15 mSv/h, resulting in an average dose of 0.25 mSv/a for a working period of 1650 h/a. The collective external dose was ~17.6 man·mSv. Although numerically small, the dose from radon is about four times higher than the dose from external radiation. The presence of high radon concentrations at some locations necessitates a detailed study of its source to apply effective control.

In a study of the radon problem in a subsurface workplace in Yugoslavia, measurements of radon emanation rates were performed at 18 locations using charcoal absorption followed by gamma counting of the radon progeny using a high purity germanium detector. Widely varying radon concentrations in the range of 44 to 3247 Bq/m^3, averaging around 1000 Bq/m^3, were observed in the emanation cylinders. Soil samples from these locations were analysed for ^{238}U and ^{226}Ra which were found to average at 41 ± 13 and 36 ± 8 Bq/kg, respectively. No correlation between the ^{238}U and ^{226}Ra contents of the soil and the radon concentrations was found.

The study reveals the existence of a significant radon exposure potential at subsurface workplaces such as building foundations, wells, wine cellars, stores and mushroom plants.

5. MINING INDUSTRY

The underground mining of radioactive or non-radioactive minerals has significant potential for exposure of workers to ^{222}Rn and its short lived progeny. External radiation exposure depends on the grade of uranium ore or on the concentration of naturally occurring radionuclides of ^{238}U and ^{232}Th decay chains.

Two papers deal with occupational radiation exposures in uranium mines and one deals with coal mining. It is clearly brought out in these papers that occupational radiation protection is given due importance in uranium and coal mines. Considerable details are given in these papers of the mandate for regulatory norms, principles and methodologies of monitoring, dose assessment and record keeping. Preservation of dose records for the lifetime of the workers or for 30 years after cessation of work is suggested in the Kyrgyz paper. The regulations regarding radiation protection in uranium, coal and other mines based on the current BSS are outlined. In Polish mines, two categories of radiation hazard have been set: Class A, where the annual effective dose is between 5 and 20 mSv; and Class B, where the annual effective dose is above 20 mSv. As in the nuclear industry, the annual dose limit in underground mines is set at 50 mSv, subject to 100 mSv during the period of five consecutive years. An inspection level of 2 mSv/a and an intervention level of 5 mSv/a are prescribed.

It appears that over 100 000 workers are exposed to different levels of ^{222}Rn progeny and about 5000 workers are exposed to gamma radiation and radium bearing mine water deposits in the Polish coal mines. The Polish coal mine data on maximum, average and collective annual doses for the period 1992–2001 show a downward trend in recent years.

The gamma exposure in four coal mines and the radon progeny levels in six coal mines exceeded the inspection levels of 2 mSv/a. The gamma exposure in three coal mines and the radon progeny levels in two coal mines were in Class A, i.e. between 2 and 5 mSv/a.

Analysis of the radiation exposure of coal mine workers during 2001 shows that 97% of workers receive doses below 2 mSv/a, 2% of workers receive between 2 and 5 mSv/a and only 1% fall into the exposure category of 5–20 mSv/a. Considering the large number of workers employed, even the small percentage in the last category represent significant numbers.

In the Indian uranium mining industry, where three underground mines produce low grade uranium ore, radiation protection measures are adopted from the beginning of the operations. Radon and radiation levels are monitored regularly to ensure compliance with regulatory norms. The monitoring data, along with the occupancy period of workers, are used to evaluate the annual doses. This ambient dosimetry is supplemented by the use of personal dosimeters by a representative group of workers.

During the five year period 1996–2000, the gamma radiation exposure rates in the three mines averaged around 2.8, 2.3 and 1.4 μGy/h, respectively. Equilibrium equivalent radon concentrations averaged around 0.46, 0.42 and 0.41 kBq/m^3, respectively. The average annual doses to workers in these mines attributable to gamma radiation and radon progeny averaged around 7.9, 7.5 and 5.8 mSv/a, respectively. The dose distribution shows that over 72% of Jaduguda mineworkers and 94% and 98%, respectively, of workers from the other two mines receive doses below 10 mSv/a. The 36 years' data presented for one of the uranium mines show that average exposures have been around 10 mSv/a with a slightly downward trend during the last few years.

6. SUMMARY AND CONCLUSION

The papers included in this session very clearly bring out the fact that exposure to natural radiation is significant in diverse areas of work, ranging from indoor and confined workplaces, oil and gas exploration and production, mining and processing of raw materials to aviation. The presence of elevated levels of NORM and TENORM in a large number of minerals and mineral products in different areas of the world necessitates a detailed survey of the industries and careful application of the exemption and clearance levels.

Large numbers of workers that work in confined workplaces, in non-radioactive mineral processing, in coal mining, in oil and natural gas production and in the aviation industry are occupationally exposed to levels of radiation that are significantly above the public dose limit of 1 mSv/a. A significant number of employees in the aviation industry, being females, require closer surveillance. A radiation protection programme in all these industries is in vogue in many countries. Similar programmes may need to be considered in other countries too. This is a major problem throughout the world. The capabilities of national regulatory authorities with regard to human resources, infrastructure, equipment, etc., and the capabilities of the countries to implement decisions need to be taken into consideration.

TOPICAL SESSION 6

DISCUSSION

S. VAN DER WOUDE: There has been a lot of talk here about ‘radioactive ore’ and I think we need to be clear as to what that term means. It may mean uranium or thorium ore in which the uranium or thorium is in sufficiently high concentration to be extracted as a primary product. But it may also mean, say, ore from which uranium, in a relatively low concentration, is extracted as a by-product, as in the gold mining industry. Whether the uranium is extracted or not will depend on the uranium price.

Consequently, you may have a gold mine which, when the uranium price rises sufficiently for uranium extraction to be worthwhile, changes category and has to be licensed as a radiation facility, or, when the uranium price falls, no longer has to be licensed as a radiation facility since uranium extraction has ceased.

Faced with this problem, we have in South Africa set an exclusion level above which ore, or any other material, is regarded as radioactive, even if activities performed with it may possibly, after consideration by the regulatory body, be exempted. The exclusion level has been set at 0.2 Bq/g for each radionuclide, which we believe to be in accordance with the International Basic Safety Standards.

However, the experts working on the question of long lived radionuclides in commodities are talking about an exclusion level of 0.5 Bq/g for each radionuclide, and such a higher level might be perceived as representing a relaxation of safety standards. Certainly, if the radionuclide were ^{226}Ra, a level of 0.5 Bq/g could mean a dose as high as 10 mSv.

Some other countries, for example, the USA and Germany, have an exclusion level of 0.2 Bq/g and it would be interesting to learn whether they would have problems with the envisaged level of 0.5 Bq/g.

T.C. CARDWELL: With dose based standards, it does not matter whether the dose is due to radiation from NORM or to radiation from human-made material; the risk is the same. I think that we should therefore regulate on the basis of risk, but that would require a lot of resources.

Something which has not so far been mentioned here is radium buildup on filters at water treatment plants. In the USA, we have started to realize that it is a problem. Is it a problem in Europe?

K. ULBAK: It is recognized as a problem in the Nordic countries, which take it into account in their processes for removing radium from drinking water.

Regarding the question of exclusion levels, in Denmark we thought that there was no need to regulate straw burning power plants. We were very surprised, however, when we measured the external radiation due to the very high ^{40}K concentration in the fly ash from such plants.

T. HEALEY: A hospital near where I live was built, in the 1970s, over a disused coal mine. In order to avoid ill effects of mine subsidence, the hospital rested on a solid concrete raft. In the 1980s, owing to concern about radon, a survey was carried out at the hospital, with detectors placed in the cellars and elsewhere. No trace of radon was found, thanks to the concrete raft. From that I conclude that prevention is better than the cure. It is cheaper to take the radon problem into account when building than to install venting systems later.

J. VAN DER STEEN: In his oral presentation, A.H. Khan spoke of 5000–10 000 workers exposed to NORM in Dutch industry. I believe that those figures are a rough estimate of the number of exposed workers within the European Union.

In his oral presentation, G.P. de Beer said that administrative measures were preferable to engineering measures. I agree that administrative measures can, for example, by raising the awareness of workers reduce doses quite a lot. However, so can engineering measures, for example, by reducing dust concentrations through better ventilation.

A.H. Khan mentioned the problem of the disposal of waste from the oil and gas industry. In some countries with deep wells, the waste can be put back underground by being re-injected into such wells after these are depleted. In the Netherlands (and some other countries), that waste disposal technique is forbidden and the waste is stored in drums. These deteriorate and the waste has to be transferred to fresh drums from time to time, which gives rise to additional occupational radiation doses. In my view, there is a need for international harmonization of the regulations in this area.

G.P. DE BEER: With regard to J. van der Steen’s second comment, engineering measures are ‘the order of the day’ in the nuclear industry. In other industries, however, where the main problem is NORM, administrative measures are likely to be more useful than engineering ones.

K. ULBAK: One way of addressing the problem of worker exposure to NORM might be to have ‘investigation levels’, above which the operator would be required to carry out a survey of the radiation situation, and ‘action levels’, above which the operator would be required to reduce the doses. If the operator was unable to reduce the doses sufficiently, a more stringent control procedure would be introduced, more or less as for normal practices.

W. BINES: That is roughly the approach we have in the UK for exposure to natural radiation, particularly from radon. We encourage people to take measurements and, if necessary, take remedial action so as not to become subject to the regulatory system.

C.J. HUYSKENS: A system consisting just of investigation levels and action levels would be beautifully simple. However, we also have exclusion levels, exemption levels and, above all, limits, and, as S. van der Woude indicated earlier this week, there is considerable terminological confusion.

Rather than step by step regulation, we need to identify and focus on those practices and situations where radiation exposure problems may arise for the workers, and perhaps also for the public.

J.H. GÖTHLIN: Essentially, that means identifying high risk places and high risk occupations. What we should probably also be doing is identifying individuals who are running a high risk, for example, the interventional radiologist who lives in a radon contaminated house and makes frequent long haul flights. That means that we must be less compartmentalized in our thinking.

Some people may feel uncomfortable about that, as it implies acquiring quite a lot of knowledge about each individual, but the individual will not benefit from our thinking purely in terms of large groups.

S.B. ELEGBA: Regarding C.J. Huyskens's point about identifying practices and situations where radiation exposure problems may arise, in my view it is not easy to establish procedures for identifying such practices and situations.

A.J. GONZÁLEZ: I agree with T.C. Cardwell that it does not matter whether the dose is due to radiation from NORM or to radiation from human-made material. Workers are going to say, "If it's possible to protect us from radiation at a nuclear power plant, why can't you protect us from the radiation in nature?"

Perhaps the problem is due to the fact that our level of ambition in the case of protection against radiation from NORM is very high.

In my view, what we need is something similar to the tier approach described by G.P. de Beer and an international consensus on basic criteria for exclusion.

In his oral presentation, G.P. de Beer mentioned that the IAEA has not issued any recommendations relating to aircrew exposures to cosmic radiation. The reason why the IAEA has not issued any such recommendations is because the relevant authorities in some IAEA Member States believe, rightly or wrongly, I don't know which, that aircrew exposures to cosmic radiation are not amenable to control. Amenability to control is the key issue and we need an international consensus regarding it.

Judging by what has happened during the past ten years or so, however, we will not arrive at one very easily.

H.-H. LANDFERMANN: There has been a lot of talk about the exposure of aircrews. What about astronauts and cosmonauts?

R.P. BRADLEY: There is a working group representing the space agencies involved in the International Space Station programme which deals with issues such as setting standards for the limitation of the exposures of the astronauts and cosmonauts who go to the International Space Station. The working group has recommended 250 mSv as a 'lifetime to date' dose which should not be exceeded.

A.C. McEWAN: An ICRP working group is looking into the question of the exposure of astronauts and cosmonauts. Some countries have a career dose limit of 1 Sv and a per-mission dose limit of 300 mSv.

K. ULBAK: We are talking here about very few people with a very special risk spectrum. Clearly, however, astronauts and cosmonauts should take an interest in their exposures.

C.J. THORP: Aircrew exposures to cosmic radiation are amenable to administrative control and the regulatory body for Canada's airlines has issued regulations relating to maximum exposures of aircrews. This is regarded as an important issue, particularly because so many aircrew members are women.

K. ULBAK: In Europe, there are such regulations, with special provisions relating to pregnant aircrew members.

R. COATES: S. van der Woude mentioned the work being done on the question of long lived radionuclides in commodities. In my view, the assumptions being made in much of the modelling connected with that work are too conservative.

A.J. GONZÁLEZ: R. Coates is absolutely right. Largely because of those very conservative assumptions, the IAEA's Secretariat is going to have to inform the General Conference of the IAEA in two weeks' time that so far no consensus has been reached in a study being conducted with a view to agreeing on acceptable levels of different radionuclides in various commodities.

The situation at present is paradoxical: the exclusion level for an edible commodity may well be higher than that for an inedible one, so that you are allowed to import one item in order to eat it but not allowed to import any equally radioactive item in order to, say, build a house with it.

The reason for the paradox is that modelling in the case of an edible commodity is relatively simple; there is a more or less agreed 'standard human' and an agreed procedure for calculating the whole body radiation dose due to the consumption of a radioactive commodity. There is no such agreement in the case of modelling for inedible commodities, so people tend to opt for very conservative assumptions in order to be on the safe side. Some of the results are absolutely ridiculous.

K. ULBAK: We seem to have strayed from the question of the radiation protection of workers.

S. VAN DER WOUDE: From various comments made this week, I have formed the impression that in the opinion of many people the radon issue has been resolved. In my opinion, it has not been resolved. For example, it has not been resolved in South Africa with regard to underground mines that are not producing uranium as a primary product. An international consensus on the radon issue with regard to such mines would be very useful.

OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL AND RESEARCH FACILITIES

(Topical Session 7)

Chairperson

B.C. BHATT
India

OCCUPATIONAL RADIATION PROTECTION IN INDUSTRIAL AND RESEARCH FACILITIES

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Abstract

This paper briefly reviews worldwide industrial/research occupational doses associated with irradiation, radiography, well logging, gauging, laboratory research and isotope production. According to the 2000 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation, 14% of the annual occupational collective dose (360 man·Sv for the period 1990–1994) derived from industrial uses, compared with 50% from the nuclear fuel cycle. Although worldwide occupational doses indicate general compliance with safety standards and a good safety record, serious overexposures occur frequently enough to cause concern. In the period 1989–1991, there were three fatal radiation accidents at irradiators. In addition, radiography overexposures continue to be frequently reported. Radiography experience in the United Staes of America included about 70 reported radiography overexposures during the period 1997 to mid-2002. Eight of these entailed acute overexposures resulting from stuck or detached radiation sources, or simple failure to retract a source, and failure to perform proper surveys. The challenges associated with industrial occupational protection include a lack of defence in depth (relative to fuel cycle operations), a large variety of work site conditions encountered and personnel limitations due, in many instances, to the small size of the organizations involved. The path forward to providing improved occupational radiation protection should include a strong emphasis on worker training, consistency of operations (seeking best practices), and co-operation and communication among regulatory authorities.

1. WORLDWIDE OCCUPATIONAL DOSES

By way of introduction this paper provides a brief overview of worldwide industrial/research occupational doses, which include doses associated with the fields of irradiation, radiography, well logging, gauging, laboratory research and isotope production.

According to the 2000 Report of the United Nations Scientific Committee on the Effects of Atomic Radiation[1], 14% of the annual occupational collective dose

[1] UNITED NATIONS, Sources and Effects of Ionizing Radiation (Report to the General Assembly), Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), UN, New York (2000).

(360 man·Sv for the period 1990–1994) derived from industrial uses, compared with 50% from the nuclear fuel cycle. Over the period 1974–1994, the number of radiation workers in industry rose from 400 000 to 700 000. This increase in the number of workers is consistent with increased global industrialization. The worldwide average annual collective dose from industrial uses over the period 1975–1984 was about 900 man·Sv, which decreased to about 360 man·Sv by 1990–1994. The average annual individual dose for industry reflected a similar trend, decreasing from 2.1 mSv in 1975–1979 to 0.51 mSv in 1990–1994. Over the period 1990–1994, fewer than 1% of monitored workers in industry are estimated to have received annual doses in excess of 15 mSv.

Although worldwide occupational doses indicate general compliance with safety standards and a good safety record, serious overexposures occur frequently enough to cause concern. These incidents generally do not receive as much public attention as incidents associated with the nuclear fuel cycle. In the period 1989–1991, there were three fatal radiation accidents at irradiators. A fatal accident recently occurred at a US irradiator, but it did not involve radiation exposure. In addition, radiography overexposures continue to be frequently reported. This paper will focus on regulatory experience with radiography and isotope production in the United States of America, in order to illustrate what the authors view as the challenges associated with future efforts to improve occupational radiation protection in industrial and research facilities.

2. OCCUPATIONAL DOSES IN THE USA: RADIOGRAPHY AND ISOTOPE PRODUCTION

It is widely recognized that the characteristics of industrial radiography field operations result in a relatively high frequency of incidents and radiation overexposures. Radiographers work in small crews, use portable equipment and work at highly variable work sites, often subject to harsh environments. Under these conditions, equipment failure and human error have a higher probability of leading to a radiation overexposure.

In the USA during the period 1997 to mid-2002, there were about 70 reported radiography overexposures. Most of these reports involved chronic doses which were not attributable to a single incident, but there were about eight incidents of acute overexposure. These involved stuck or detached radiation sources, or simple failure to retract a source, or failure to perform proper surveys. The doses generally exceeded 250 mSv whole body, and ranged from 1 to 30 Sv to the exposed extremities. In several cases, there were observable injuries to the extremities.

In the area of isotope production, in 2000, a major US radiopharmaceutical producer reported numerous annual extremity exposures to the fingertips ranging from 1 to 4 Sv. These exposures occurred over several years, and resulted from poor handling procedures and inadequate assessment and monitoring of potential doses. The Nuclear Regulatory Commission (NRC) conducted follow-up inspections at about 200 licensees to check for similar problems and identified potential problems at several additional facilities.

These events also illustrate the need for increased attention to, and optimization of, occupational doses. The management and radiation safety staff should have paid closer attention to whether the workers were following appropriate handling procedures when they were in close proximity to radioactive material. In many cases, an overexposure is the result of failing to properly control and reduce routine exposures.

3. THE CHALLENGES ASSOCIATED WITH INDUSTRIAL OCCUPATIONAL PROTECTION

There are many issues associated with radiation protection which are common to all uses of radiation. However, the focus here is on the challenges which are unique to industrial uses.

Lack of defence in depth: Power reactors and most fuel cycle facilities have large physical plants, with elaborately engineered safety features. The engineered features of industrial operations are much more limited. Therefore, industrial workers rely to a large degree on proper procedures and human performance to ensure safety.

Variety of conditions: Industrial facilities are much more numerous and varied than are nuclear power facilities. Therefore, it is more difficult to standardize safety equipment and procedures with respect to recognized safety criteria. This allows for more variation among operations according to the knowledge and capabilities of the individual operators. The lack of standardization increases the probability that an unsafe condition will continue unrecognized and uncorrected, and lead to a radiation overexposure.

Personnel limitations: Many industrial uses involve small organizations that do not employ full-time radiation safety personnel, and the radiation safety training is limited to the minimum required by regulatory authorities. These circumstances reduce the safety margin for normal operations, and still further for unusual incidents, because an operator may not have adequate training to enable them to correct an unusual, unsafe condition.

For example, in the USA in early 2002, a radiography source was ruptured by inadvertent contact with a high voltage cable, creating extensive contamination in a tank and over an outdoor area. This presented unusual safety challenges because a ruptured radiography source is rare. Fortunately, in this case, the response personnel restricted the area and controlled access, and there were no serious overexposures.

The NRC continues to move towards a risk informed, performance based, regulatory approach. This means that, when appropriate, the NRC sets the safety outcomes to be achieved, rather than prescriptive requirements, and licensees have the flexibility to select the safety equipment and procedures needed to achieve adequate safety. However, in areas of higher risk, where defence in depth and engineered safety features are limited, prescriptive requirements are sometimes imposed. For example, radiographers are required to work in teams of two and are required them to wear audible alarm dosimeters. These prescriptive measures decrease the probability that an unsafe condition will be allowed to continue and possibly result in an overexposure.

In addition, the authors agree with the generally recognized principle that adequate training of users of radioactive material is critically important. Adequate training increases the likelihood that operators will follow proper safety procedures under normal conditions, and will not respond in an unsafe manner during accidents or unusual conditions.

4. CONCLUSIONS AND PATH FORWARD TO IMPROVED OCCUPATIONAL RADIATION PROTECTION

In considering these challenges, the authors believe that there are three areas which can be addressed by the international radiation protection community:

(1) *Worker training*: The importance of worker training should continue to be emphasized.

(2) *Consistency*: Wherever possible, areas of inconsistency among similar operations should be evaluated and best safety practices identified. This will promote safety improvements in organizations which have not adopted generally recognized safety practices.

(3) *Co-operation and communication*: Finally, co-operation among regulatory agencies should continue and co-operation among users of radioactive material should be encouraged, so that there is a broad understanding of safety problems, lessons learned, corrective actions and general safety procedures.

Commendable IAEA initiatives which will promote sharing of event information are the International Nuclear Events Scale and the Radiation Events database. These systems promote worldwide sharing of information about nuclear events.

Continued efforts in these areas will serve to reduce incidents of overexposure and will also improve optimization of routine exposures in the industrial/research fields. Our goal should be to reach a point where overexposures become so infrequent that our primary focus then becomes the optimization of routine exposures.

RAPPORTEUR SUMMARY

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1. INTRODUCTION

The six papers presented in this session fall into the following groupings:

(a) Two papers on the follow-up of accidents involving industrial radiography,
(b) One paper on the testing and certification of industrial radiographers,
(c) Two papers on control of occupational exposure in a university environment,
(d) One paper on issues related to the handling of spent sources from industrial and medical facilities.

2. INDUSTRIAL RADIOGRAPHY

2.1. Follow-up of accidents

The paper by Jalil [1] describes the follow-up of the effects of overexposure to an ^{192}Ir industrial radiography source and lessons learned from it. The accident itself occurred in 1985 and involved a 1.85 TBq ^{192}Ir source, housed in a portable exposure assembly, being used for the radiographic investigation of a gas pipeline. The 'storyline' is a classic: a remote location; the source becomes decoupled, probably during the first of 18 exposures, and is not noticed by the radiographer because he failed to use a dose rate meter. The radiographer received a whole body dose of 2–3 Gy and displayed the classical symptoms of acute radiation syndrome. In accidents such as this it is highly likely that the hands, when handling the guide tube, will come into close proximity with the source. This was the case in this accident, with doses to parts of the hand estimated to be 24 Gy. The main part of the paper focuses on a long term review of the effects on the hands, key elements being:

(a) Loss of some terminal phalanges,
(b) Reduction in bone density,
(c) Skin and deeper tissue not stabilizing,
(d) Brittle bone at the end of finger tips,
(e) Continuing pain.

The case provides a contribution to the body of medical experience, but perhaps it is the litany of such long term effects that might be of most use in gaining the attention of industrial radiographers during their training. The paper identifies several contributory causes:

(a) Working alone,
(b) Poor training,
(c) Not following rules and regulations,
(d) Lack of a radiation monitor.

These are common failings in industrial radiography and may provide a useful focus for further discussion.

The paper by da Silva et al. [2] discusses reconstructive dosimetry with respect to the accident that occurred in Brazil in 2000 during maintenance work on a remote exposure container housing a 2.11 TBq ^{60}Co source in a shielded facility. The source had not been fully retracted into the safe position, and as in the previous paper, a dose rate monitor had not been used. After 21 days the left hand of the radiographer presented serious lesions indicating doses to these parts of the hand of between 12 and 20 Gy (assessed on the basis of the timing and severity of the lesions). The paper focuses on various reconstructive dosimetry methods to assess dose distribution on the left hand. The purpose was to provide an auxiliary tool for medical evaluation and to facilitate the establishment of medical procedures for treatment of the patient. The reconstruction methods indicated that the exposure profile of the hand was only consistent with the source having been between 1 and 3 cm inside the internal channel of the device. Impressive use was made of a hand phantom and dosimeters to assess the dose distribution.

2.2. Issues for discussion

A common feature of both the accidents reported was the conspicuous failure to use a radiation monitor. The author recalls his introduction to radiation protection 34 years ago. Within a few weeks he had been taken, as part of his training, to help investigate an industrial radiography accident involving a remote exposure container (similar to the two reported cases). The source had become decoupled from the drive cable and the radiographer had failed to use a monitor to check that the source was safe. In his naivety the author thought that this was such a fundamentally simple problem that improvements in equipment, training and management could easily eliminate such accidents. Yet here we are over three decades later and such accidents still regularly occur around the world. If it were possible to ensure that radiographers used a dose rate meter after every exposure to check that the source had returned to the safe position, the vast majority of industrial radiography accidents could be eliminated.

The issue is one of how to improve the safety culture of an industry where the work is often undertaken in adverse conditions with limited supervision and driven by commercial pressures. The roles of the following in influencing the safety culture is something that the Conference may wish to address:

(a) The regulator: Is there a regulatory framework and effective enforcement?
(b) The qualified expert: Is enough use made of them?
(c) The client has safety responsibilities; enforcing safety standards for work on its premises will have a commercial influence.

2.3. Training

Training is obviously a key element in addressing the underlying problem. In the author's experience this can be of very varied quality — to the extent that he would have 'failed' some of the training courses. Thus, it is important to assess the effectiveness of the training. The paper by Cardwell [3] on testing and certification of industrial radiographers reviews the approach taken in Texas. Driven by a high occurrence of industrial radiography accidents, the Texas Department of Health (Bureau of Radiation Control) in co-operation with the US Regulatory Commission developed a certification programme for industrial radiographers. The test was developed to ensure that anyone acting as an industrial radiographer knew the basic principles of radiation protection. The paper covers the development of the examination and a question bank. From its inception in 1987 up to January 2002 some 10 700 examinations had been conducted in Texas with a 24% failure rate. The paper also attempts to examine the metrics of how this knowledge is put into effect by evaluating the statistics of reported incidents. However, there have been a number of confounding factors: variation in the volume of work driven by oil price fluctuations, and changes in legislation and reporting procedures. Although it was not possible to draw positive conclusions on the impact of the testing and certification scheme, one is left with the distinct impression that it was a worthwhile initiative.

3. UNIVERSITY RESEARCH ENVIRONMENT

The university research environment is radically different to that where industrial radiography is undertaken. In many institutes, a qualified expert will be available as a member of staff, and thus advice on radiological protection matters will generally be readily available. However, the complexity of a university environment can pose its own problems in terms of getting advice translated into effective actions. The two papers here present quite different situations.

The paper by Vacarri et al. [4] covers radiation safety in Mössbauer laboratories. The source activities in use are somewhat lower than those found in industrial radiography, i.e. up to 3.7 GBq ^{57}Co and 185 MBq ^{119}Sn^{m}. They are also used in relatively well-defined circumstances. Nevertheless, there is a need for clear and effective radiological protection arrangements. The paper covers what might be described as the classical arrangements required by the Basic Safety Standards of both the IAEA and the European Union (EU).

The paper by Tschurlovits [5] from the University of Technology, Vienna, covers control of occupational exposure in a university research reactor. This is a radically different situation: it covers the use of a TRIGA MkII reactor (250 kW) and associated irradiation facilities, suites of radiochemical laboratories, accelerators, X ray equipment and a range of sealed sources. The paper identifies a number of areas where there are difficulties in terms of control and legal compliance. In addition to permanent staff, the university has a floating population of temporary scientists (e.g. on short term fellowships) and students/guests. Many scientists work in more than one institute and the nature of the experiments is continually varying. This is a problem common to many research environments. Similarly, defining the boundaries of controlled areas can be a common problem. However, the solution at the University of Technology is not common; the whole of the institute is classified as a controlled area, with concomitant problems.

The thrust of the paper is that the standards embodied in the EU Basic Safety Standards are designed for different operational constraints than those that apply in a university research environment. The paper notes that doses are low and that the EU Basic Safety Standards have not effected any substantial change to them. The paper concludes:

> "A modern university style requires flexibility and mobility of the staff and students. International standards do not pay sufficient attention to this. The effort is not considered fully justified, even taking into account that good radiation protection practice has to be demonstrated for educational purposes."

No doubt this provocative conclusion will stimulate debate at the Conference. However, the author would:

(a) Draw a distinction between international goal setting standards (and their underlying principles) and the way these are embodied in national legislation (and, in turn, how this is implemented);

(b) Caution that the educational element of good radiation protection practices should not be underestimated.

4. DEALING WITH SPENT SOURCES

In the remaining paper of the session, Ortiz [6] covers occupational radiation protection in the handling of spent sources from industrial and medical facilities from a Spanish viewpoint. The paper reviews the radiation protection programme of the Spanish National Waste Management Company (ENRESA). While the nuclear industry conditions its own waste, that derived from research, industry, medicine and agriculture is conditioned by ENRESA. A comprehensive radiation protection programme ensures that doses are kept very low. For authorized installations with good records of their sources, dealing with the radiation protection issues arising from conditioning the waste is relatively simple. However, it is interesting to note that in many cases the waste results from old practices that have never been authorized, or from sources that have been abandoned, lost or misplaced. Here the uncertainty of what is being dealt with makes the radiological protection issues more challenging.

The problems of dealing with spent sources and the potential for these to become orphan sources have been covered by other IAEA conferences and initiatives. Perhaps from the author's viewpoint the underlying good message is that at least in Spain it is being positively addressed. One would like to hope that other countries are being as positive.

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TOPICAL SESSION 7

DISCUSSION

J. DUFFY: When a licence for industrial radiography work is issued to a company in Ireland, only the names of qualified persons, of industrial radiographers who have been certified, may appear on the licence. A person who has not been certified may work only as an assistant industrial radiographer — under supervision.

The licence is issued for a period of one year and the licence conditions are specific to the type of practice in which the company is involved. At the end of the year, the company must apply for a renewal of the licence and a check is made on whether the company has been complying with the conditions, which relate to things such as safety procedures, dosimetry records, and the availability and calibration of radiation monitors.

Regarding the question of lessons learned, I recommend the IAEA publication Lessons Learned from Accidents in Industrial Radiography (Safety Reports Series No. 7).

As to training, the IAEA has developed a very good training package for regulators on the authorization and inspection of radiation sources in industrial radiography, which I have used and can recommend.

I.A. GOUSSEV: The IAEA has sent medical teams to various Member States after radiation accidents in industrial radiography and other practices. Such help is extremely valuable, but there is also a need for medical centres specialized in dealing with radiation injuries. Perhaps the IAEA could encourage the establishment of such centres.

T.C. CARDWELL: In my paper IAEA-CN-91/94, which describes a programme for the Testing and Certification of Industrial Radiographers, it is stated that the programme is considered to have had a positive impact on the safety record of the oil and gas industry in Texas. In that connection, I would mention that, in cases where industrial radiographers who have passed the test provided for under the programme and have accordingly been issued with a certification card and then fail to make proper use of the knowledge which they demonstrated by passing the test, the Bureau of Radiation Control of the Texas Department of Health can withdraw the certification card, permanently or for a certain period.

B.C. BHATT: The certificates of industrial radiographers in India may be suspended, the duration of the suspension depending on the seriousness of the non-compliance with the regulations.

W. BINES: Many small companies, especially ones which do not work with ionizing radiation themselves, lack the expertise necessary to assess whether outside industrial radiographers visiting their sites are working safely. One of our inspectors has therefore helped devise a simple training programme for enabling the managers of such companies to make such assessments and, if necessary, challenge the visiting industrial radiographers. An article by that inspector is available on the ‘Radiation’ pages of the Health and Safety Executive’s website.

J.R. CROFT: The IAEA publication Lessons Learned from Accidents in Industrial Radiography mentioned by J. Duffy is very useful. However, in a developing country where I was recently investigating an industrial radiography accident, the members of the regulatory body claimed that they had never seen that publication; certainly the industrial radiographers involved in the accident had never seen it. This illustrates the difficulty of ensuring that useful guidance literature reaches those who would benefit from it.

In this particular developing country, the regulatory body is also the sole provider of personal dosimetry services, so I suggested that each personal dosimeter sent out by the regulatory body be accompanied by a newsletter containing one or more case study reports; and I gave the regulatory body a large number of case study reports, for translation into the local language and inclusion in such newsletters, so that they might be read by the country’s industrial radiographers.

J. CREMONA: I am an industrial radiographer and I would say that in countries where there is no regulatory body (or where, as in the case of Malta, the regulatory body is in its infancy), the companies which engage in industrial radiography are free to do more or less whatever they like, so that much depends on the company policy regarding safety. In our company, all the industrial radiographers are qualified to European Norm 473 and have taken a course in radiation source retrieval. Should something go wrong with the equipment, we know what to do without advice from a regulatory body.

O.K. AWAL: In the International Basic Safety Standards, it is stated that “Qualified experts shall be identified and made available for providing advice on the observance of the Standards.” In Bangladesh, this requirement has caused us problems and I should like to hear how it is met in other countries.

J.R. CROFT: In the UK, the vast majority of organizations using ionizing radiation (including all industrial radiography organizations) have to appoint qualified experts, who are called ‘radiation protection advisers’. The National Radiological Protection Board (NRPB), for which I work, is radiation protection adviser to about a thousand organizations operating in the non-nuclear sector. The NRPB’s radiation protection professionals have accumulated a great deal of experience in their radiation protection adviser role and can, for example, pass on information about good practices which they have observed. An important part of their job is to encourage managers to instil a high level of safety culture throughout the organizations which they manage.

B.C. BHATT: With regard to O.K. Awal’s comment, I would mention that in some countries the regulations require that organizations using ionizing radiation have radiation safety officers (or whatever the title) but most organizations cannot afford to have full-time radiation safety officers and would therefore benefit from a system whereby they can hire the services of freelance radiation protection officers approved by the regulatory body. In India, at least, such a system does not yet exist.

O.K. AWAL: In radiotherapy, the radiation protection officers are usually highly qualified professionals. In the case of small scale industrial radiography operations, however, that is not economically feasible. What can one do?

J.R. CROFT: In the UK, each organization using ionizing radiation has a 'radiation protection supervisor' — a permanent member of the staff who has had some training in radiation protection but is not a radiation protection professional. The radiation protection supervisor is the focal point for managing radiation protection within the organization and liaises with the qualified expert, who is a radiation protection professional.

In many developing countries, the regulatory body may have to perform the role of qualified expert and that of radiation protection supervisor.

F.I.M. NOLAN: The Radiation Safety Institute of Canada, in co-operation with provincial governments and regulators, industry and trade unions, is putting great emphasis on education and training. In particular, it is training general health and safety inspectors in radiation safety since they have tended to be reluctant to ask questions about radiation safety in the workplace. The training programme is similar to the radiation safety officer training programme but designed to meet their special requirements.

The need, worldwide, for education and training in radiation safety is enormous. In Canada, a developed country, it is substantial, but in a country such as China it is, judging by what Ziqiang Pan has said, far greater. From African colleagues I gather that in Africa alone there are some 300 000 people exposed every day to ionizing radiation in the workplace.

Even at technical universities and research institutes there are occupational radiation protection problems, for one cannot assume that people such as nuclear physics professors understand radiation safety. Our experience suggests that radiation safety culture at such establishments is almost non-existent.

E. AMARAL: Some time ago, we found that, because of commercial pressures, some organizations providing industrial radiography services were neglecting various safety procedures in an effort to provide such services faster than their competitors. We had to exercise our regulatory powers in order to deal with the situation. However, we were also faced with an ethical problem in that connection, namely, whether it was proper for us to let prospective users of industrial radiography services know which providers were operating safely, as the information could be exploited for commercial purposes.

J.R. CROFT: I see no ethical objection to the regulators making such information available. Industrial radiography is a very competitive business and users may well simply opt for the cheapest service unless they have been given such information.

From the point of view of the regulator, it is important to put pressure not only on providers but also on users, who have a duty to care for the people working at their sites and should heed information given to them by the regulator.

A.J. GONZÁLEZ: I should like to mention two problems which have not been considered here.

The first problem is the occupational radiation protection of people such as transport workers and customs officers who monitor for illicit trafficking in radioactive materials. Strict adherence to the IAEA's Code of Conduct on the Safety and Security of Radioactive Sources would help, but States have been reluctant to assume serious obligations in this area.

The second problem is that of occupational radiation protection in countries which are not Member States of the IAEA. Some of these countries have large numbers of powerful radioactive sources in use (Turkmenistan, for example), and workers from IAEA Member States may well be employed there. Perhaps those IAEA Member States which have nationals who are radiation workers in countries not belonging to the IAEA should take an interest in that problem.

G. SALLIT: As the person in charge of radiation protection at the UK Atomic Weapons Establishment, I should like to describe briefly how, after a number of small incidents due to the failure of radiographers to monitor at all times, we have changed our approach to safety in the field of radiography.

Previously, radiographers were simply sent on a training course and then made to take an examination. Now, a qualified expert — a recognized expert in radiography — accompanies the certified radiographer in order to see whether what we require is actually done in practice. We have found that the radiographers now monitor at all times.

In addition, our certified radiographers are required to participate in a source retrieval exercise every 2–3 years. So far, they have received advance notice of such exercises, but now we are thinking of introducing unannounced exercises.

OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR FACILITIES

(Topical Session 8)

Chairperson

A.P. PANFILOV
Russian Federation

OCCUPATIONAL RADIATION PROTECTION IN NUCLEAR FACILITIES

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Abstract

This paper presents an overview of the global situation in terms of occupational exposures in worldwide nuclear facilities from 1974 to 1990 and highlights some specific issues for radiation protection over the next decades. The stages and facilities considered in this presentation of the evolution of occupational exposures are the following: uranium enrichment and conversion facilities, nuclear fuel fabrication plants, reactor operation and nuclear fuel reprocessing plants. The data presented are based on the United Nations Scientific Committee on the Effects of Atomic Radiation 2000 Report and the International System on Occupational Exposure database, and illustrated in some cases with respect to the French situation for nuclear power plants. Reflections on the status of the 'as low as reasonably achievable' (ALARA) principle are proposed, showing that ALARA has been the driving force of radiation protection. Two issues for the future of occupational radiation protection are discussed: the case of itinerant workers and the decommissioning of nuclear facilities. The conclusion addresses the need to continue spreading the radiation protection culture among the various actors and the development of networks of actors, in order to favour the sharing of experiences in radiation protection practices and to create a dynamic of progress for the protection of workers.

1. INTRODUCTION

The objectives of this paper are to present an overview of the global situation in terms of occupational exposures in worldwide nuclear facilities and to highlight some specific issues for radiation protection over the next decades. The stages considered in this presentation for the evolution of occupational exposures are the following: uranium enrichment and conversion facilities, nuclear fuel fabrication plants, reactor operation and nuclear fuel reprocessing plants. The focus is on nuclear power plants as they represent the major source of occupational exposures. The data presented are based on the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report [1] and the Information System on Occupational Exposure (ISOE) database [2, 3], and illustrated in some cases with respect to the situation for French nuclear power plants. For all data presented, it has to be kept in mind that averaged data only present global trends and always mask discrepancies between facilities.

2. EVOLUTION OF OCCUPATIONAL EXPOSURES IN NUCLEAR FACILITIES

2.1. The present situation in the nuclear fuel cycle

The UNSCEAR 2000 Report [1] provides data concerning the evolution of the collective and individual doses for the different stages of the nuclear fuel cycle.

The average annual occupational collective dose over five year periods (1975–1994) associated with each stage are presented in Fig. 1. The main contributor to the average annual collective dose was the operation of nuclear reactors, with around 1000 man·Sv/a. The other stages were far lower, with around 50 man·Sv/a for fuel reprocessing, 20 man·Sv/a for fuel fabrication plants and 1 man·Sv/a for uranium enrichment and conversion facilities.

In order to better estimate the evolution of radiation protection in the different sectors, it is important to put into perspective the evolution of the average annual collective dose with respect to the evolution of electricity production (which indirectly represents the number of operating facilities). This can be done by calculating the average annual collective dose per unit energy generated (see Fig. 2). When looking at the evolution of this indicator, it appears that for the operation of nuclear reactors major progress has been made in reducing occupational exposures since 1975: the average annual collective dose per GW·a was reduced by nearly a factor of three,

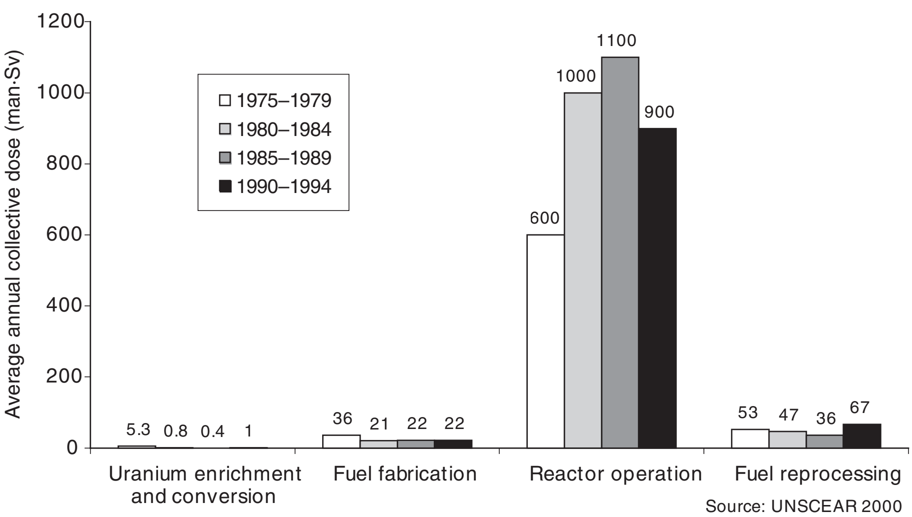

FIG. 1. Worldwide average annual collective dose from the commercial nuclear fuel cycle.

from 11 man·Sv/GW·a to 4 man·Sv/GW·a. For fuel fabrication, the decrease in the average annual collective dose was also substantial, with a factor of five reduction. For uranium enrichment and conversion facilities, the level of the average annual collective dose per GW·a was stable over the period. The only sector where an increase of the average annual collective dose per GW·a was observed was in fuel reprocessing, with an increase of a factor of three for the last period (1990–1994). However, this result has to be treated with caution as it has been calculated using the equivalent energy generated from the previous period, owing to a lack of data from the reporting countries.

In terms of average annual individual doses to monitored workers, a decrease was observed in all sectors compared with 1975–1979 levels (see Fig. 3). For the last period (1990–1994), the average annual individual dose in the different sectors was around 1–1.5 mSv, except in uranium enrichment and conversion facilities where it was in the order of 0.10 mSv. These averaged data should be taken as global indicators of the general trend. They do not represent the reality of the distribution of individual doses, as they are averaged over the totality of monitored workers, which is far higher than the number of workers actually receiving a measurable exposure. Another factor which is not taken into account in these numbers is the fact that many workers may work in different facilities (itinerant workers). The dose reported by one facility is then not representative of the total dose incorporated by this type of worker. For a clearer and more realistic picture of individual occupational exposures, it would

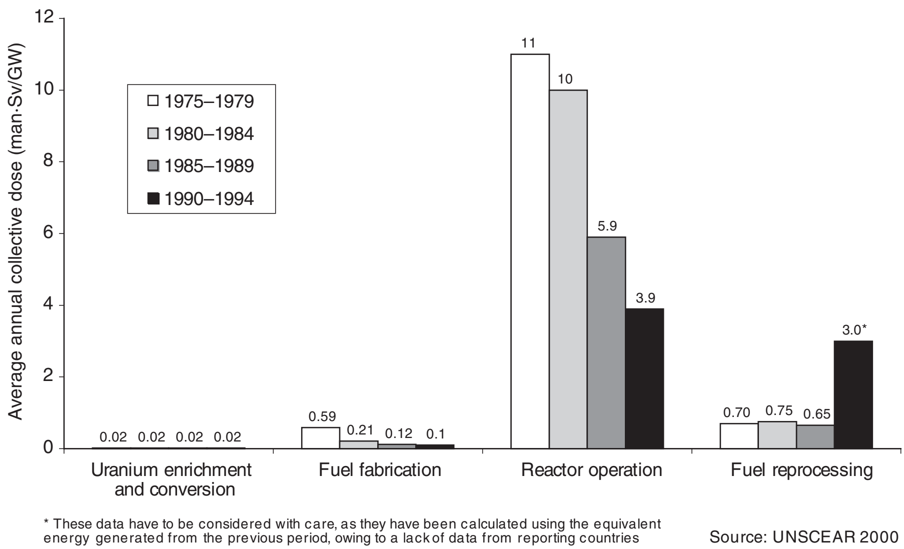

FIG. 2. Worldwide average annual collective dose per unit energy generated from the commercial nuclear fuel cycle.

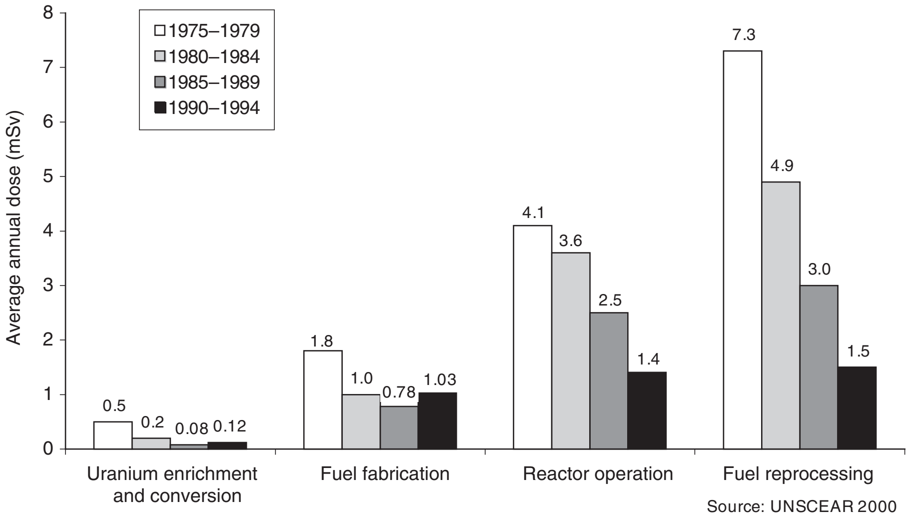

FIG. 3. Worldwide average annual effective dose to monitored workers from the commercial nuclear fuel cycle.

be necessary to have national or even international databases assigned according to the sector of activity.

2.2. Detailed elements for the nuclear power plants

2.2.1. ISOE data

As reactors are the main contributors of the nuclear fuel cycle in terms of collective dose, a brief summary is given on the evolution of occupational exposures in this sector. The data are taken from the ISOE database on nuclear power plants, promoted and sponsored by the OECD Nuclear Energy Agency (OECD/NEA) and the IAEA, which provide a Joint Secretariat for the programme.

Over the period 1985–2000, despite the increasing number of operating reactors[1] (from 225 to 337 reactors), the total collective dose per GW·a was reduced by nearly 70% (from 6.2 man·Sv/GW·a in 1985 to 1.5 man·Sv/GW·a in 2000) (see Fig. 4).

This global trend towards a decrease of the collective dose can be particularly observed with BWRs and PWRs, as shown in Fig. 5 which presents the average

[1] The number of operating reactors corresponds to the number of reactors for which the total collective dose per year and the total annual production were available in the ISOE database. GCRs are not included in this evaluation owing to the lack of representative data in the ISOE database.

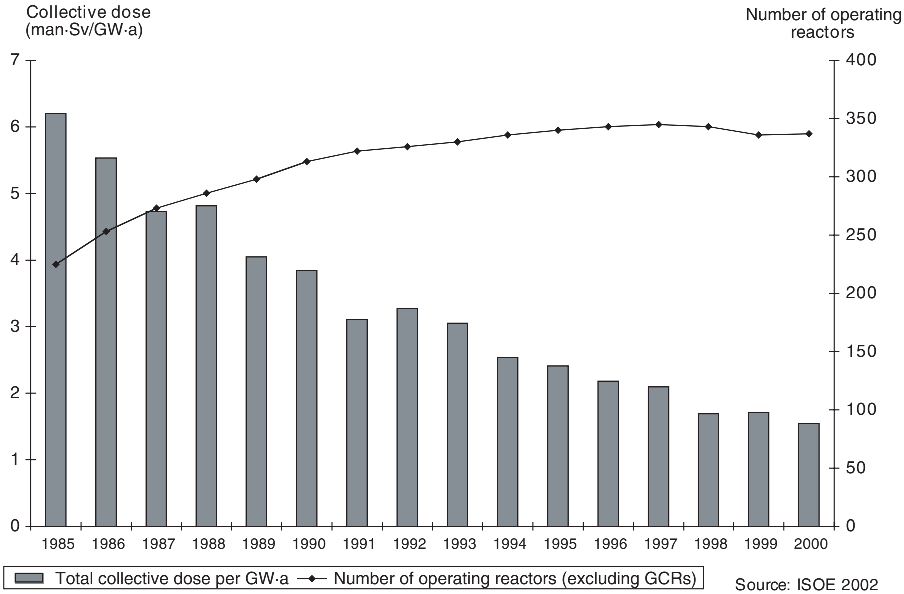

FIG. 4. Total collective dose per GW·a and number of operating reactors (excluding GCRs) included in ISOE database for 1985–2000.

collective dose per reactor from 1985 to 2000. The average collective dose per reactor is currently around 2 man·Sv for BWRs and 1 man·Sv for PWRs, WWERs and CANDU reactors. It should be noted that the ISOE database also contains data for three LWGRs, which presented a collective dose per reactor of 6 man·Sv in 2000.

One major maintenance operation performed in nuclear power plants is the replacement of steam generators. Between 1979 and 2000, 58 steam generator replacements were performed, mainly in North America and Europe. Collective doses decreased regularly from more than 6 man·Sv per steam generator replaced in the late 1970s to early 1980s to an average of about 0.5 man·Sv during the last six years (see Fig. 6). However, the average data mask quite large discrepancies and the best results correspond to three steam generator replacements performed in 1996 and 1998 in Belgium and France with only 0.21 man·Sv per steam generator replaced. The performance observed for this specific maintenance operation is a good example of the impact of the integration of feedback experience in reducing the level of occupational exposure. However, it should be noted that this operation usually benefits from having a well-planned organization and specific human and financial resources, which is not always the case for ‘common’ maintenance operations in nuclear power plants.

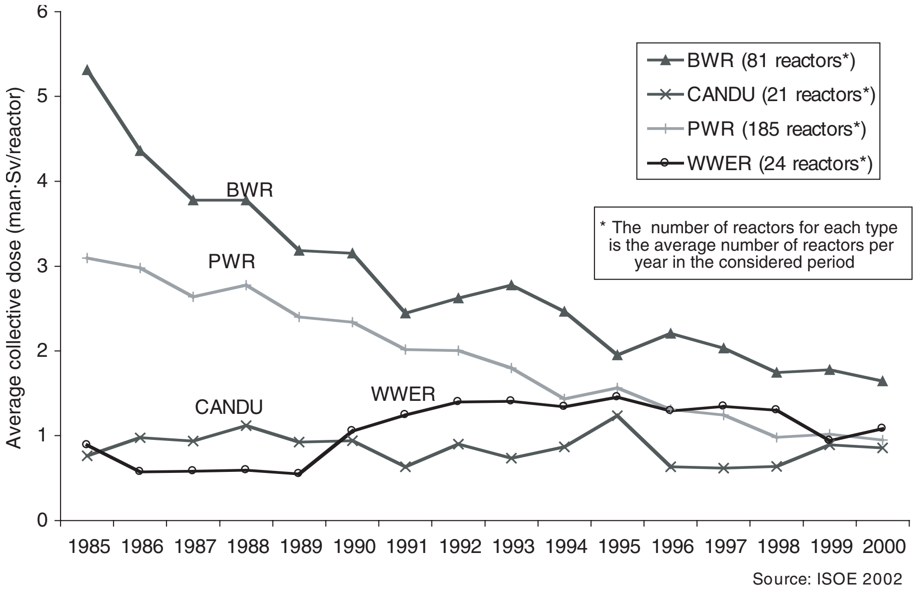

FIG. 5. Average collective dose per reactor for operating reactors included in ISOE by reactor type for 1985–2000.

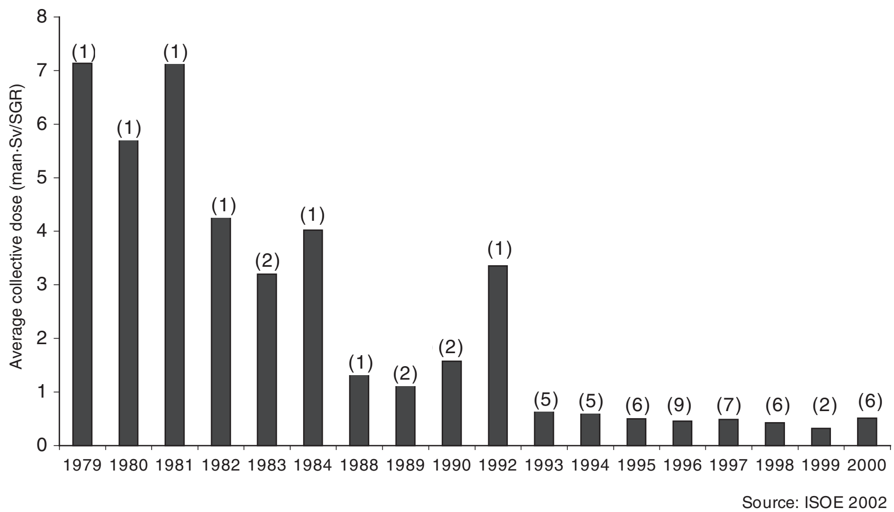

FIG. 6. Evolution of the average collective dose per steam generator replaced between 1979 and 2000. The number of steam generator replacements is shown in parentheses.

2.2.2. Electricité de France data

The French utility Electricité de France (EDF) is operating 58 PWRs, the last two reactors having been connected to the grid since 2001. Major progress in terms of reduction of collective and individual doses has been made during the last decade, by the implementation of specific 'as low as reasonably achievable' (ALARA) programmes. The average collective dose per reactor decreased from 2.3 man·Sv/reactor in 1992 to 1.02 man·Sv/reactor in 2001 (see Fig. 7). It is also interesting to analyse the impact that the initial design of the reactors has had on the collective dose. In Fig. 8, it can be observed that the average collective dose per reactor for 1300 MW reactors (2nd generation in France) is half that of 900 MW reactors (1st generation).

In order to take account of itinerant workers, EDF has created an operational dosimetry network connecting all plants (the so-called DOSINAT system [4]). This system permits assessment of the total annual individual dose received by any worker working in EDF plants. When examining the distribution of the mean annual individual doses of contractors and EDF workers, it can be observed that the reduction of collective doses during the last decade has been accompanied by a reduction of the mean individual doses and by a reduction of the highest individual doses (see Fig. 8).

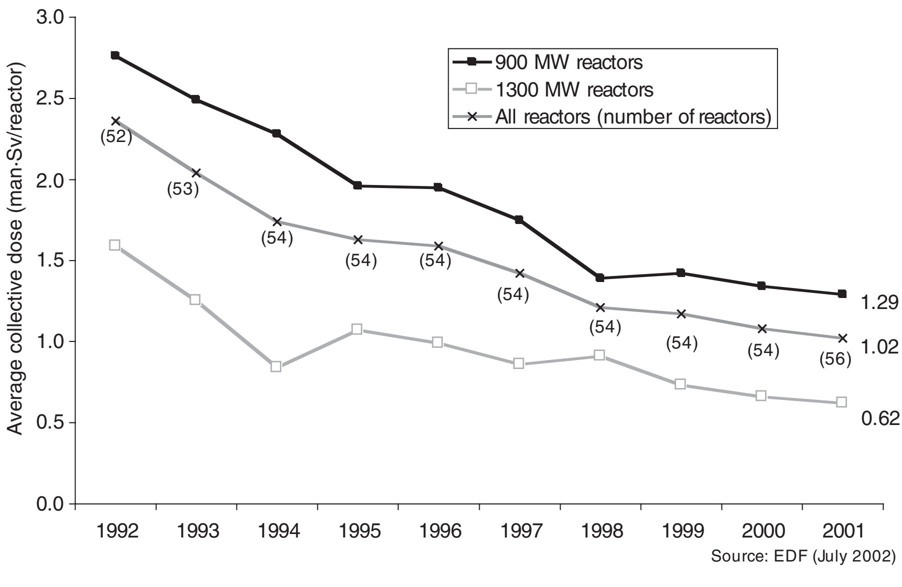

FIG. 7. Average collective dose per reactor in France by reactor type for 1992–2001.

The DOSINAT system also provides information on the evolution of individual doses per occupational category. This type of analysis is essential if the priorities to be given in the radiation protection actions are to be identified. Figure 9 shows an example of the analysis of the individual dose per speciality for 1997–2001. It appears that the most exposed category of workers are insulators, with a mean individual dose of 7 mSv in 2001. Mechanics, scaffolding workers and welders were in the range of 3 mSv in 2001. The mean individual dose for workers performing control and inspection jobs was around 2 mSv in 2001. For electrical and instrumentation workers, the mean individual dose was close to 0.9 mSv in 2001. Above the mean individual dose, specific attention has also to be given to specialized workers such as welders, as the duration of their training is long and costly, and as only few workers are available.

3. OPTIMIZATION OF RADIOLOGICAL PROTECTION

3.1. Status of the implementation of ALARA principle

The progress made in all sectors in reducing exposures shows that the ALARA principle has been the driving force of radiation protection. The willingness to maintain or reduce doses ALARA, taking into account economic and social considerations, has progressively transformed the radiation protection organization and

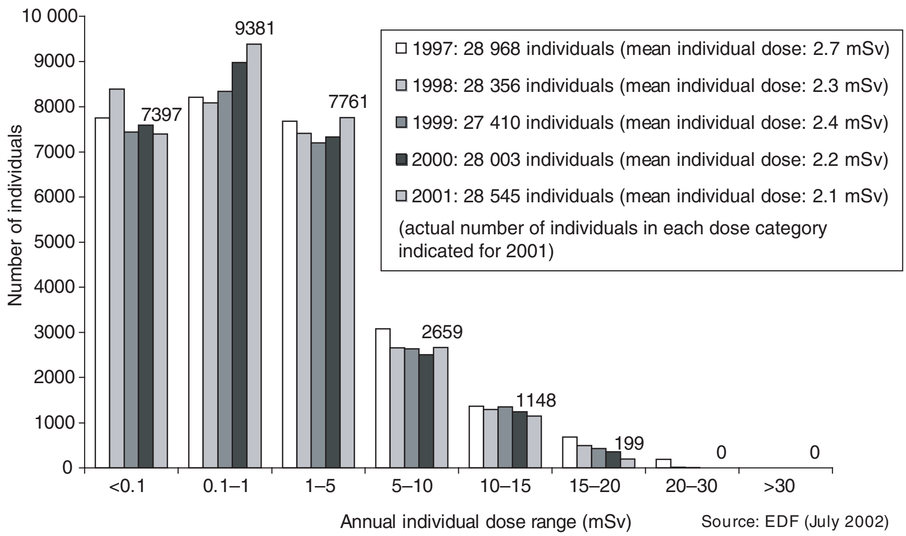

FIG. 8. Distribution of annual individual doses in French nuclear power plants for 1997–2001.

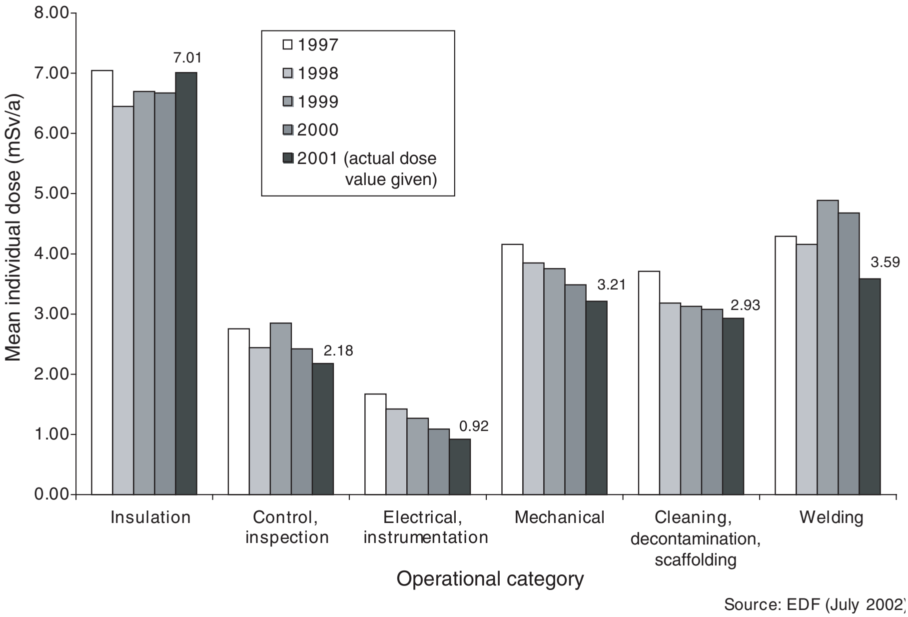

FIG. 9. Mean individual doses per occupational category in French nuclear power plants for 1997–2001.

culture. The practical implementation of the ALARA principle has also benefited from the development of international recommendations (International Commission on Radiological Protection [5, 6], OECD/NEA [7], IAEA [8, 9]) which permit the development of an international culture among the radiation protection professionals.

The role of regulation in this evolution was also essential to initiate the process and maintain a high level of commitment in all parties involved. Depending on the national context, the authorities interact more or less with the operators in the implementation of the ALARA principle. Whatever the case, it is usually recognized that there is a need for an open and constructive dialogue between the authorities and the operators to promote the definition and implementation of ALARA programmes.

Within the elements to be considered in ALARA programmes as a means of reducing exposures, progress has been made in the consideration of the non-technical factors which can influence the duration of works in radiation fields. As such, work management actions, including work planning and scheduling, training of workers, promoting awareness and involving workers, have been given more specific attention in the preparation of works to be performed in radiation areas. The technical factors that have facilitated decreases of radiation sources (i.e. control of water chemistry, decontamination techniques, use of specific shieldings) and/or improvements in the efficiency of tools have also benefited from development and research in the framework of ALARA programmes.

Another important aspect in the development of the ALARA principle is the establishment of national and international databases on occupational exposures, as well as the creation of networks in order to increase the sharing of past experience. At the international level, for nuclear power plants, the ISOE[2] provides both a database on occupational exposures and a network of contact persons in utilities and among the authorities [2]. At the European level, a network (European ALARA Network (EAN)) was created in 1996 by the European Commission to further specific European research on topics dealing with the optimization of all types of occupational exposure, as well as to facilitate the dissemination of good ALARA practices within all sectors of European industry and research, including nuclear facilities [10]. The main yearly goals EAN are to: (i) provide two issues of a European ALARA newsletter, to be largely distributed and available on a web site[3] and reflecting some major aspects of the ALARA situation in Europe, and (ii) organize one ALARA workshop. This type of network should be developed on a worldwide basis in order to continue the spreading and sharing of information on experiences among the different sectors concerned by nuclear activities.

A frequently asked question concerns the costs of implementing ALARA programmes and actions. It is, however, quite difficult to give a quantified answer, as no global data are available. Actually, these costs are relatively complex to estimate. This is partly due to the fact that many dose reduction actions lead to a reduction in some operating costs (reduced workload, shortened outage duration (for nuclear power plants), fewer protective suits used), and produce, finally, a benefit in terms of net operating cost.

3.2. The place of cost–benefit analysis

Even if some authorities and utilities have adopted reference monetary values for the unit of collective dose (the so-called ‘alpha value’), an international survey performed by CEPN at the request of EDF in 1997 on the use of alpha values by authorities and nuclear power plant utilities shows that cost–benefit analysis plays a restricted role in the implementation of ALARA programmes [11].

The values recommended by the radiation protection authorities are baselines rather than directly operational tools. They almost never have regulatory status.

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[2] ISOE web site: http://www.nea.fr/html/jointproj/isoe.html.

[3] EAN web site: http://ean.cepn.asso.fr.

Most of the sites and the operators replying to the survey have themselves developed monetary value systems for the man-sievert. In three quarters of cases, the values are used less than ten times a year.

In all the countries, the formal use of the monetary value of the man-sievert is restricted to decisions regarded as particularly important, whether in budget terms, or in terms of impact on operations or installation safety. This value is not used as a 'decision making tool', but as a 'decision aiding tool', helping to reduce subjectivity in the decision making process. In most cases, it is no more than one criterion among others. Once the operator has adopted a system of monetary values of the man-sievert, it is used as an effective transaction tool between partners — in the relationships between operator and sites, and in relationships with contractors or radiation protection authorities.

However, even if the result of a decision aiding technique such as cost–benefit analysis is only one criterion among others in the decision making process, the use of such a technique is useful as it permits structuring of the problems, identification of the decision criteria and quantification of the various elements needed (collective dose, distribution of individual doses, effectiveness of radiation protection techniques, etc.). It is also a good way to introduce transparency into the decision making process.

3.3. The future of ALARA

The practical implementation of ALARA is essentially linked to the development of a radiation protection culture among the stakeholders (authorities in charge of controlling the implementation of radiation protection regulations, management staff, designers of facilities, designers of tools and working procedures, workers), ensuring that all 'actors' integrate the radiation protection dimension in their day-to-day work.

The components of a radiation protection culture are quite similar to those of a safety culture. Three main domains need to be addressed: the knowledge, the regulatory and organizational frameworks, and the individual values and behaviour. Concerning the knowledge domain, a key element to be shared by all actors is awareness about the nature of radiological risk, which can be gained mainly through specific training sessions. These training sessions, which have to be adapted to the type of occupational category concerned, should also integrate elements on the means of protection (technical means, behaviour in radiation areas, etc.).

The regulatory and organizational frameworks are essential in delineating the field of responsibilities of all actors. They express the commitment of actors (authorities, management of facilities) towards radiation protection. For example, it is by the elaboration of radiation protection programmes that the management can favour the implementation of radiation protection actions and create the conditions for the sharing of a 'common project' within the facility, 'maintaining exposures ALARA'.

Finally, there is a need for a commitment at the individual level; for exposed workers, this commitment is expressed by the adoption of attitudes and behaviour favouring their own protection. For non-exposed workers whose activities may have an influence on the level of exposure of others, it is essential that they integrate the radiation protection dimension into their activities. The motivation of all actors has to be supported by the acknowledgement of their actions.

4. SOME FUTURE OCCUPATIONAL RADIATION PROTECTION ISSUES

The intention here is not to draw up an exhaustive list of issues, but rather to point out a few elements of interest for the radiation protection community.

4.1. Itinerant workers

In some sectors of nuclear activities (e.g. reactor operations), itinerant workers and contractors form a large part of the exposed workers, and the practices related to the control of these workers are quite different and vary according to the country and the utility.

Although the primary responsibility for the protection of these workers lies with the management of the organization in which they work, ultimate responsibility lies with the registrant/licensee of the facility which employs these workers, and which is also responsible for the radiation protection of all individuals working in its facility. If the agreement between the contractor and the facility related to the sharing of radiation protection responsibility is not clearly stated, there will be an overlapping of responsibilities which can be a source of inadequate managerial control over the itinerant workers.

Another issue related to itinerant workers concerns their dose control. They can, for example, at each location where they are working, receive a dose below the individual dose restriction fixed by the facility for the purpose of internal individual exposure management, but accumulate in one year a significant exposure due to the number of locations where they have been working.

For workers going to work in several countries, problems may arise from the non-harmonization of dose limits between these countries. For example, some European countries have adopted the individual dose limit of 100 mSv over 5 years with a maximum of 50 mSv for any one year. Other countries have adopted an individual dose limit of 20 mSv/a. Here again, specific agreement between the employers and the registrant/licensee has to clearly delineate the accepted dose limit.

For any facility employing contractors, there is also a need to verify whether the contractors have received the same radiation protection and safety training that its own workers have, and, if not, to provide this training before starting work.

4.2. The decommissioning of nuclear facilities

The decommissioning of nuclear facilities will concern numerous countries over the coming decades, either as a result of the ageing of installations or owing to the willingness of some countries to stop producing nuclear energy. The contribution of decommissioning to the total occupational collective dose will then increase progressively. The experience with decommissioning is still limited and efforts need to be made to prepare for these future activities.

Preparations for decommissioning must take account of some specificities which differentiate this type of activity from usual maintenance operations. The decommissioning will usually take place several years after the definitive shut down of the plant, and this can induce, if not prepared well in advance during the operating period, a loss of ‘memory’ of the installation. This loss of memory may concern the knowledge of the design of the installation (especially if modifications have been performed since the original design), as well as the origin and level of radioactive sources. The preparation of the work and the prediction of occupational exposures may then be significantly complicated.

Another uncertainty induced by the integration of this medium term dimension is related to evolution of radiation protection standards: how to elaborate dosimetric objectives for operations that will take place in 20 or 30 years’ time without knowing what the norms for occupational exposures will be in this time? It will certainly be necessary to elaborate different scenarios of decommissioning and to make them evolve according to the potentially new standards of protection.

From the technical point of view, in addition to the issue of lack of knowledge on the future technology available, the question of the management of internal exposures will have to be addressed. According to the preliminary plans for the decommissioning of nuclear facilities, it appears that it may be necessary to accept the possibility of low levels of internal exposure in order to avoid the wearing of protective clothing which may interfere with the jobs to be done. The management of internal exposures is quite specific from an optimization of radiological protection point of view as the level of these exposures is usually difficult to estimate a priori, and as the ‘real time’ dosimetry systems are not always available or efficient. Only a few experiences of practical ALARA procedures for the management of internal exposures exist, and it will be necessary in the future to further explore this field.

5. CONCLUSION

The last two decades have been characterized by the substantial progress made in occupational radiation protection, as shown by the reductions of individual and collective exposures in spite of the general increase in electricity generated. However, it has to be kept in mind that the figures presented in this paper reflect an average situation and may mask discrepancies between countries or between facilities in the same country. Vigilance is still needed in order to maintain a good standard of radiation protection and to detect the places where substantial improvements are necessary.

Many factors have contributed to the general reduction of occupational exposures. The design of facilities, integrating feedback experience from previous facilities of the same type, and/or integrating at the very beginning of the design stage radiation protection criteria and objectives have been, and will continue to be, key elements for the reduction of occupational exposures. Another factor which has contributed significantly to the reduction of occupational exposures is the practical implementation of the ALARA principle which requires the adoption by the facilities of appropriate technical and organizational measures, and to the spreading of a radiation protection culture among the various actors of the nuclear sector. This radiation protection culture is essential in order to favour dialogue between actors, to ensure collective and individual responsibilities towards radiation protection, and to maintain vigilance with regard to the radiological risk.

Finally, an important issue for the future is to continue the development of networks of actors, at the national and international levels, in order to favour the sharing of experiences in radiation protection practices and to create a dynamic of progress for the protection of workers in all nuclear facilities.

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RAPPORTEUR SUMMARY

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1. INTRODUCTION

The authors are to be commended for the high standard of their thought provoking papers. The experience covered has been gained mainly with operating reactors, thereby excluding other areas such as reprocessing and decommissioning. A number of papers cover both the operational and environmental safety aspects of nuclear facilities and whilst this reflects the importance of a holistic approach to operating nuclear facilities, this review concentrates on the occupational aspects. The aim of this summary is to review the papers submitted in a broad way, focusing on issues and themes that arise or are indicated by the content.

2. RADIOLOGICAL PROTECTION STATUS

The first clear message emerging from the collection of papers is that the application of occupational radiological protection in nuclear facilities is, in the main, a success in that dose limits are being achieved, often by a considerable margin. The 'as low as reasonably a achievable' (ALARA) principle is universally applied in one form or another and is often claimed as the means by which significant improvements have been achieved in recent years. The attention given to ALARA is also reflected in the frequent reference to collective dose as an important measure of performance. Interestingly, the term 'cost–benefit analysis' is not a term mentioned in any of the papers, which is quite a change of emphasis when compared with the position in the 1980s. ALARA is judged to be effective when it becomes part of normal job planning and is second nature with formal optimization utilized only when the radiological implications are very significant [1].

In most facilities, the only major concern referred to is external gamma radiation and there is little personal monitoring reported for neutrons and extremity exposures, suggesting that these are now of second order importance. Internal exposures are also referred to relatively infrequently, with only the CANDU reactors presenting a significant dose component with tritium [2].

It is worth reflecting on this success and identifying which factors have contributed to this situation. The paper from Mexico [3] provides important clues with regard to the overall improvement that has been achieved since a system of independent licensing was introduced. Many of the papers point to the importance of clear standards and a legislative framework which requires a safety management system. Usually this involves an independent regulatory body [4] and requires a policy and objectives, the identification of performance measures, planning and implementation arrangements, and regular review and audit. The Mexican experience, in common with that of most other countries, requires the appointment of radiation protection officers who must be directly involved in task planning, worker training, etc. The importance of a formal method of ensuring the appointment of educated and trained personnel as radiation workers [5] is particularly crucial where the aim is to change and improve safety culture and behaviour.

It should be possible to transfer and build on the key elements of this radiological success to improve the control of non-nuclear hazards both within and outside the nuclear industry.

3. INDIVIDUAL DOSE CONTROL

The use of collective dose is noted in a number of papers, with one paper [1] stating that reductions in individual dose should not be at the expense of increased collective dose. Another paper [6] also touches on the topic of dose constraints to operationally limit individual dose limits. Although collective dose provides a useful performance measure, particularly when comparing facilities performing a similar function, the workforce sometimes views it, along with average dose, with some concern as both can mask individual doses. Many papers refer to a move towards a workforce culture that encourages the exercising of more personal control over working arrangements. In future, this might lead to more emphasis being placed on controlling individual doses as performance indicators.

The opportunity for workers to take personal control of their working arrangements and exposure has become possible through better understanding and training and by access to technology such a personal alarmed dosimeters, video, etc., which provide real time information and simulation to help control and influence actions. This is certainly the case for external exposures but less so for internal where there is normally a time delay between the exposure at work occurring and the results of that exposure becoming available.

It is important that certain factors be in place before providing the freedom of action that such programmes encourage and to ensure that aberrations from normal are monitored. The aim of enabling more workplace decisions to be taken must be achieved within a framework that has effective engineered and procedural barriers and which assumes that the worker remains within the safe operating envelope.

4. DOSE REDUCTION

It seems important that nuclear facilities have a name or phrase to assist the process of dose reduction and the term ALARA has been used in many countries as a synonym for dose reduction. Dose reduction in existing facilities can be viewed as adopting cost effective engineered options such as shielding, introducing procedural controls and exploring programmes to change behaviour and attitudes — often referred to as 'culture'. Changes to a proactive culture may be more difficult to introduce into older plants and where cleanup decommissioning activities are under way because the defence in depth may not be available and the work may be undertaken by short term contractors. It is just these areas where exposures can be significant and where most benefit can perhaps be gained.

It is possible that placing more emphasis on individual dose control could generate a move from collective to individual dose reduction techniques [1]. This could lead to a move away from engineered protection and towards the use of personal protective equipment, which could be regarded as a retrograde step in routine operational activities. This may be a trend worth monitoring over the coming years, particularly as facilities change stages in their life-cycle.

A number of papers (including Refs [5, 6]) point to good dose reduction practice by:

(a) The incorporation of defence in depth safety into the facilities;
(b) The use of a priori dose objectives;
(c) The adoption of clear source term control requirements, e.g. decontamination before maintenance, water chemistry;
(d) The use of specific control measures for internal exposure, e.g. ventilation, dust reduction measures.

It is important that good practice principles be clearly stated, such that all involved fully understand the basis of the control regime in which they operate.

A further message arising from the papers concerns the importance of collecting good data from the facilities to enable effective interpretation and identification of trends. There are examples within the papers where good data have identified high dose jobs that require attention. The data collected should cover not only the immediate needs but also future requirements, e.g. for decommissioning.

5. OPTIMIZATION

The optimization process is time dependent, with new facilities at the design stage affording more opportunities for eliminating hazards and engineered controls. Older facilities are often constrained in the control options available and plants undergoing clean up and decommissioning often did not have decommissioning features designed in. For many facilities, the evidence in the papers suggests that the remaining engineered opportunities are limited and that procedural controls such as classification of areas, etc., and worker culture are the remaining cost effective avenues for improvement. Time is also a key issue when assessing decommissioning options in terms of dose [7]. This may be a timely opportunity to consider whether facilities can be optimized for their remaining life-cycle, including decommissioning and remediation, i.e. improvements made to further reduce dose during operation may have an adverse impact on decommissioning.

It is worth remembering that a radiological hazard is only one hazard that must be balanced and optimized with the other hazards encountered in the work environment. Nuclear facility operators may therefore seek to optimize their total hazard in occupational activities and the challenge to the radiation protection community will be to assist with this process given its lead in this field.

6. CONTROL OF CONTRACTORS

A number of papers point to the often significant difference in exposures between the workforce and contractors [6, 8, 9]. In one instance cited, the contractors employed for outages receive 95% of the total dose [9]. The use of outside workers to perform specialized tasks at shutdown often represents a sensible approach to human resource planning and to effective radiological protection. However, the difficulty arises from the fact that many non-routine tasks can involve higher than normal exposures and with workers moving between nuclear facilities in one country, or even between countries, it can be difficult to control the total exposure of this group. The experiences gained in Lithuania and the Czech Republic demonstrate higher exposures to contractors. Slovenia has adopted a central dose register such that *all* workers in the country, including contractors, are monitored, even when they move between facilities. On the basis that we cannot effectively control and optimize that which is not measured there is a need for a review of the control and dose measurement arrangements for workers who move from facility to facility, particularly between countries. China [10] reports maintenance work being moved from contractors to plant workers and certainly each facility must ensure that proper plant knowledge is retained and remains available for contingencies. The internal dose resulting from work is often of little significance in nuclear facilities, but the implications for control do need to be considered for this group [9]. Another aspect to consider is how these workers will be effectively assimilated into, and benefit from, cultural change programmes which could vary from facility to facility.

7. LEARNING FROM EXPERIENCE

An important feature of effective safety management systems is the capability to learn from experience and to seek continuing improvement. The information gained also enables safety to be built in, providing defence in depth [5]. Without this learning component there is a danger of stagnation and complacency. There is clear benefit in an effective legal framework, as evidenced in Refs [4–6], that requires regular review and audit both by operators and by regulators. There is, however, also great benefit in being able to exchange successes and failures in the safety field worldwide. The World Association of Nuclear Operators system [10] and the IAEA audits are examples of such exchanges but, on the evidence of references cited in the Ref. [10] references, the international community needs to consider whether more can be achieved, particularly when the languages are not common. This Conference is a prime means of encouraging such exchanges, but more regular and effective contacts should be considered.

8. INCIDENTS

Only one of the papers [9] mentions the effect of incidents, although given the low routine exposures recorded by most individuals they represent the biggest potential for adverse exposures, particularly from internal exposure. Incidents also act as the trigger for much of the general concern over nuclear power safety and can increase worker stress levels. From an optimization viewpoint it may be worth reviewing whether all avenues are being explored to minimize non-routine events.

9. DEMONSTRATION OF SAFETY

Following on from the learning from experience issue is the need to demonstrate to the world that civil nuclear power is a viable, safe and environmentally sustainable source of electricity and heat. The presence of clear standards is an important step and the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources is an important document. Adoption of other standards such as ISO 14001 [5] are also clear indicators that environmental quality is being incorporated. France [4] reports a methodology for a comprehensive occupational radiological review which begins with first principles and covers the whole life-cycle of nuclear facilities. At the operational level it develops a system to encourage the adoption of safety requirements as an integral feature of nuclear facilities rather than as an add on. At a broader level it prompts the question of whether there is benefit in considering the development of a clear international radiological safety standard capable of acting as a clear demonstration of safe practice and thereby providing reassurance to stakeholders.

10. CONCLUSION

In conclusion, the papers represent a series of thought provoking examples of radiation protection from nuclear facility operators. They are very encouraging and reflect the international and national efforts being made to meet clear radiological protection standards. The success of occupational protection worldwide is demonstrated and there would be merit in identifying the critical success factors to enable the messages to be transferred to other safety hazards. An emerging message is also that the individual is taking more control of their own exposure and that more emphasis may be directed towards individual control measures. It is worth remembering that radiation is only one hazard, which must be balanced with the other hazards encountered in the workplace. At the international level there may be merit in considering a standard for radiological protection.

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TOPICAL SESSION 8

DISCUSSION

G. SALLIT: At the UK Atomic Weapons Establishment we have achieved significant collective dose and maximum individual dose reductions through an ALARA programme in which, besides senior management, plant managers and radiation protection professionals, the trade unions were involved. The involvement of the trade unions was very useful since it is the people they represent who receive the radiation doses, and hence have a strong interest in the success of the ALARA programme, and who have a detailed understanding of what is done in the workplace. Many of the changes made in the course of the programme cost very little, thanks to the involvement of the workers' representatives.

J.H. GÖTHLIN: In my view, there must be responsibility for radiation protection at the level of the individual radiation worker, who needs to know the total dose which he/she receives in the course of the day and the dose which he/she generally receives in the working place. That may mean that you have to record the total dose received during a week in order to single out the radiation workers who are at high risk, either because they are doing high risk work or because they are exposed to a high radiation background. Radiation workers who are at low risk require general surveillance; those who are at high risk should be monitored and be immediately warned if they are exposed to high dose rates.

Regarding the cost–benefit analysis of ALARA, I used to do a lot of it some 20 years ago, when it was fashionable. However, you cannot really put a monetary value on the harm to society caused by invalidity due to radiation in the workplace. In any case, the cost–benefit analysis will always turn out in favour of the employer.

G.G. EIGENWILLIG: Also regarding the cost–benefit analysis of ALARA, since 1989 we have another measure for enforcing ALARA in Germany — a lifetime dose maximum of 400 mSv.

There may be exemptions (a worker may continue at work, receiving an annual dose of less than 10 mSv, if a medical specialist and the regulator agree), but the introduction of that lifetime dose maximum has resulted in a large reduction in radiation exposure at, for example, nuclear power plants.

Many utility representatives said that introduction of the 400 mSv lifetime dose maximum would cost a lot of money. It did not. The necessary changes were mainly organizational ones, based on better work planning, and they were made very quickly.

Many utility representatives also said that it would cost a lot of jobs. Again, it did not. The employers were very interested in retaining their trained staff, given the high cost of training new people. In addition, introduction of the 400 mSv lifetime dose maximum was strongly supported by the trade unions.

J. ISHIDA: With the ageing of the occupational radiation protection community, it is becoming more and more important to attract young people into occupational radiation protection. I should be interested to hear views about how this can be done.

D.C.D. URQUHART: I was pleased that both the keynote speaker, C. Schieber, and the rapporteur, R. Anderson, referred to contractors. In the UK, we regulators have noticed that contractors are involved in a disproportionately large number of radiation incidents.

With regard to decommissioning, there may be occupational radiation protection benefits to be had from delaying it. However, other factors must be borne in mind, for example, the risks to the public and to the environment during the period of safe storage. It is not easy to strike the necessary balance.

I congratulate the occupational radiation protection specialists on having reduced routine radiation exposures in the workplace. Now, I would like to see more emphasis being placed on making sure that nothing goes wrong and on mitigating the consequences when something does.

With regard to the role of regulators, they can be a nuisance. In my view, however, they do act to the net benefit of those whom they regulate, or they should; if there are cases where they do not, we should like to be informed. Without independent and objective regulators, who can the operators, the employers, the public and the politicians turn to and ask "Is it safe?"

C. ARIAS: ALARA means the reduction of individual doses and of collective doses, but, according to the ICRP, it also means the reduction of the risk of accidents. I would have liked to see more emphasis placed on this aspect of ALARA.

R.W. ANDERSON: So would I.

G.A.M. WEBB: One purpose of decision aiding systems is to make clear the things which should be considered in the taking of decisions. If some of those things involve ethical difficulties, the decision aiding system should help to resolve the difficulties, not hide them.

In the early days of the use of cost–benefit analysis, there was a tendency to regard the 'alpha value' as a magic number rather than as a basis for taking an ethical decision about the allocation of resources in order to improve radiation protection, which is what it really is.

After 20–30 years of use, cost–benefit analysis still has, with the newer decision aiding systems, a role to play with regard to the taking of decisions, namely, that of making the decisions more transparent.

From his oral presentation, I gathered that R. Anderson was of the opinion that we needed an international standard in the field of occupational radiation protection. I thought we had such a standard.

R.W. ANDERSON: We do have such a standard. What we do not have is a mechanism for checking against that standard, in order to demonstrate that the radiation protection system at a particular nuclear facility is comprehensive and robust.

J. VAN DER STEEN: I agree with D.C.D. Urquhart that a number of factors must be borne in mind when one is thinking about delaying the decommissioning of a facility. A particularly important factor is the loss of knowledge about the facility if the delay is a long one. Such loss of knowledge could lead at the time of decommissioning to higher occupational doses and even to higher doses to the public.

R.W. ANDERSON: That is very true. Even after a decommissioning delay of only ten years we have had difficulty in finding important information.

C. SCHIEBER: Delays between shutdown and decommissioning have rarely been for the purpose of allowing radioactive decay to reduce occupational exposures at the time of decommissioning; they have usually been due to other considerations.

At Mol, it was necessary to contact retired workers in order to gain a better understanding of what had been done years before with a research reactor that was now being decommissioned.

S. VAN DER WOUDE: In his oral presentation, R. Anderson talked about balancing the radiological hazard with the other hazards encountered in the workplace. That is difficult if only because occupational radiation protection professionals do not speak the same 'language' as the professionals who deal with the other hazards. As I indicated in Round Table 1, there is a need for terminological harmonization at the international level.

R.W. ANDERSON: I agree.

F.I.M. NOLAN: Further to what G. Sallit said, I should like to underline the importance of communicating effectively with the workers at nuclear facilities.

We at the Radiation Safety Institute of Canada were recently called upon to look into problems at a plant where there had been unexpected ^{14}C exposures and at one where there had been tritium exposures. In both cases, the problems about which the workers were concerned were largely non-technical and of the ten recommendations which we made only three related to technical matters. The problems were due mainly to breakdowns of communication between, on the one hand, the health physicists and, on the other, the workers.

A. SUGIER: I agree with D.C.D. Urquhart that we tend to talk too much about routine radiation exposures in the workplace and not enough about preventing radiation incidents or mitigating the consequences of such accidents. Perhaps occupational radiation protection professionals regard potential exposures as a general safety issue. If they do, there is a need for rethinking, since every year there are serious radiation incidents, some of them even at fuel cycle facilities.

M. CHAMPION: In response to a comment by G.A.M. Webb, R. Anderson spoke about the need for a mechanism for checking against the international standard in the field of occupational radiation protection. At the Institut de radioprotection et de sûreté nucléaire, we are trying to develop such a mechanism.

J. BILLARD: As a workers' representative, I should like to emphasize the importance of consulting with the workers and of doing so in such a way that the workers can be justifiably confident that their views will be heeded, even if those views are critical of, say, a manager who has a decisive say regarding their pay and their future employment prospects.

In that context, I would say that it is no coincidence that worker dose reductions have been greatest at those plants where the workers are well organized.

R. COATES: As regards communicating with radiation workers, I should like to recall the simple but useful slogan “distance, shielding, time”. In the early drafts of ICRP Publication 75, the slogan was “distance, shielding, time, awareness”, but then “awareness” disappeared, unfortunately in my opinion, for, as this Conference has shown, awareness is extremely important.

A.S. TSELA: With regard to J. Ishida's comment about attracting young people into occupational radiation protection, I should like to see the IAEA organizing regional workshops for young radiation protection professionals.

R.P. BRADLEY: The importance of effective exchanges of experience within the nuclear power sector has been rightly emphasized, but there is also a need for effective exchanges of experience between, on the one hand, people working within that sector and, on the other, people working in, say, the medical sector. There is even a need for such exchanges with people working in fields such as tool design and manufacture.

V. KUTKOV: In implementing the International Basic Safety Standards and the recommendations in ICRP Publication 60, we have found that the contribution of internal exposure to average individual dose at Russian nuclear fuel cycle facilities is 20–25% (it can be over 50% at ‘hot spots’). We therefore have a special programme for controlling the internal exposure of the occupationally exposed people at those facilities.

C. SCHANDORF: At this Conference we have tended to talk about the risk of stochastic effects rather than the risk of deterministic effects, even though it is the latter risk about which the public is concerned; even scientists want to be assured that they are safe. Should we be talking about radiation protection or about radiation safety? I agree with those who feel that we are focusing too much on routine exposures.

G.P. DE BEER: I would not like the individual dose and collective dose maxima set for the nuclear industry to be converted into standards for other industries. If they were, that would result in a great expenditure of money on things that are not important.

PROBABILITY OF CAUSATION OF OCCUPATIONAL HARM ATTRIBUTABLE TO RADIATION EXPOSURE

(Topical Session 9)

Chairperson

D.J. BENINSON
Argentina

EPIDEMIOLOGICAL STUDIES OF OCCUPATIONAL EXPOSURE TO IONIZING RADIATION

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Abstract

Occupational exposure to ionizing radiation occurs, or has occurred, in a variety of ways and many groups of workers have been the subject of epidemiological study. Dial luminizers who inadvertently ingested radium based paint experienced a clear excess risk of bone tumours, and underground hard rock miners who inhaled radon and its decay products have an unambiguously raised risk of lung cancer. Studies of these heavily exposed groups have generated risk coefficients for these cancers. Nowadays, individual doses received by workers are much lower and exposures are limited by a regime of radiological protection. The risk models underlying radiological protection are based principally upon studies of the Japanese atomic bomb survivors, with appropriate conservative generalizations being made to deal with the different exposure circumstances. Epidemiological studies of radiation workers offer a direct check of these assumptions. Those studies of nuclear industry workers that have been carried out have produced reassuring results, but the accuracy of the derived risk estimates is limited. To achieve high accuracy, large numbers of workers must be studied over long periods. A large international collaborative study is under way and this may achieve the goal of obtaining reliable risk coefficients directly from the experience of radiation workers.

1. INTRODUCTION

It is beyond reasonable doubt that moderate to high doses of ionizing radiation increase the risk of cancer [1, 2]. However, at present, radiation induced cancers cannot be distinguished from the background of other cancers (although the search for biological markers of radiation exposure and causation continues (see, for example, Refs [3–5])), so risks must be assessed epidemiologically. For low linear energy transfer (LET) radiation, risk estimates have been established principally through the study of the Japanese survivors of the atomic bombings of Hiroshima and Nagasaki, and of patients who have been highly exposed for therapeutic purposes. Enhanced exposure to radiation also occurs in an occupational setting. The level of occupational exposure is currently controlled through a system of radiological protection, primarily based on the risk coefficients derived from the experience of the Japanese atomic bomb survivors, but in the past some exposures have been high. The epidemiological study of workers exposed to increased levels of radiation is of importance because certain groups of workers who have been heavily exposed to radioactive materials have provided risk estimates for specific sites of cancer. Such worker studies also allow the epidemiological validation of the generalizations required to apply the risk estimates derived from Japanese atomic bomb survivors to the circumstances of exposure presently experienced occupationally.

Occupational exposure to radiation occurs, or has occurred, in a number of ways. The medical application of ionizing radiation in diagnostic radiology or radiotherapy inevitably involves the exposure of medical staff concerned with its administration. Similarly, those involved in the industrial applications of radiation such as industrial radiography will experience enhanced exposure. Exposure to radon and its decay products in underground hard rock mines has led to a clear increase in the risk of lung cancer, and it should not be forgotten that workers in factories or other surface buildings can be exposed to levels of radon that are greater than those experienced in their homes. Elevated exposure to radiation from naturally occurring sources also occurs in other occupational settings, such as an increased exposure to cosmic radiation of those involved in air transportation and an enhanced exposure to radioactive dust in mines and ore processing plants (see, for example, Ref. [6]). In the past, radium has been ingested by workers applying luminous paint to dials and by chemists, sometimes in significant quantities. Finally, those working in the nuclear energy and weapons industries experience elevated levels of ionizing radiation.

2. OCCUPATIONALLY EXPOSED GROUPS

2.1. Medical staff

The application of ionizing radiation to medicine was one of its first technological uses after its discovery towards the end of the 19th century. Some of the exposures experienced by medical workers in the early years of the 20th century were comparatively large and, indeed, one of the first pieces of epidemiological evidence that radiation exposure increases the risk of malignant disease was the report by March [7] in 1944 of an excess of deaths from leukaemia among radiologists. Results of studies of medical personnel have been summarized by Carpenter [8], and reports of excesses of leukaemia and solid cancer in medical workers continue to occur in the scientific literature, for example, the study in China by Wang et al. [9]. Although the number of individuals occupationally exposed in a medical setting is large, doses were generally highest in earlier years when there was no monitoring of radiation dose at an individual level. The absence of individual dose estimates is a major obstacle to deriving risk coefficients from studies of medical workers. However, with the increasing diversity of medical techniques involving radiation and the dose records now maintained for medical personnel, these radiation workers may contribute to the risk estimates derived from future epidemiological studies.

2.2. Radium dial painters

Workers, mainly women, employed to apply luminous paint to watch and instrument dials inadvertently ingested the radium based paint [1, 2]. Radium concentrates in the bone and there is a clear excess of bone cancer among those luminizers with high intakes of radium. There are difficulties in deriving accurate doses from ^{226}Ra to the cells sensitive to the induction of bone tumours, but estimates have been made allowing the derivation of risk coefficients for bone cancer. The luminizers also experienced an excess of cancer of the paranasal sinuses and mastoid air cells which is attributed to exposure to radon and its decay products liberated during the decay of radium deposited in the bone. There is also some evidence of an excess risk of breast cancer in the luminizers which may be due to enhanced external irradiation from the pots of paint situated in front of the women.

2.3. Underground hard rock miners

Underground hard rock miners are exposed to raised levels of radon and its decay progeny. Epidemiological studies of these miners around the world have demonstrated an unequivocal radon related excess risk of lung cancer [1, 2]. Sophisticated analyses of the combined data from these studies have allowed detailed risk models for radon induced lung cancer to be derived which take into account such factors as time since exposure and exposure rate [10]. The excess risk of lung cancer broadly increases linearly with cumulative radon exposure and the excess risk at low occupational exposures is compatible with that obtained from epidemiological studies of high residential exposures. This suggests that an excess risk of lung cancer also exists in other occupational settings such as coal mines (see, for example, Ref. [11]), and buildings with elevated levels of radon. The influence of cigarette smoking, the dominant risk factor for lung cancer, upon the risk of exposure to radon has been difficult to determine because of the high prevalence of smoking among miners, but it would appear that the risk from smoking and that from radon produce a combined risk that is more than additive and somewhat less than multiplicative [10]. The studies of underground hard rock miners have not revealed an excess risk of cancers other than lung cancer [10].

2.4. Nuclear industry workers

The large numbers of workers who are, or who have been, employed in the nuclear energy and weapons industries form a particularly suitable group for the epidemiological study of occupational exposure to radiation at low dose rates. It is usually the case that dose records exist for nuclear industry workers, and that personal information is sufficiently detailed as to allow unambiguous follow-up of workers to identify cause of death and, possibly, cancer registration. At the predicted low levels of excess cancer risk, it is necessary to follow large numbers of nuclear industry workers for long periods to achieve risk estimates that are sufficiently accurate as to allow a meaningful comparison to be made with predictions based upon the risk models underlying radiological protection. To date, most large studies of nuclear industry workers have been carried out in Canada, the United Kingdom and the United States of America, although preliminary results from workers in the former USSR who generally experienced higher levels of exposure have recently been published [1, 2]. The International Agency for Research on Cancer (IARC) study of combined nuclear industry workforces in Canada, the UK [12] and the USA found a statistically significant trend in leukaemia mortality with increasing cumulative dose that was at a level compatible with that found in the Japanese atomic bomb survivors. No significant excess risk of solid tumours was detected in this study, but the risk coefficient was consistent with that predicted by standard risk models.

3. DISCUSSION

Epidemiological studies of the radium luminizers and underground hard rock miners have led to risk coefficients for bone cancer and lung cancer, respectively. The radon related lung cancer risk coefficient obtained from the studies of underground miners is sufficiently accurate to be used as a risk estimate in its own right [1, 2]. However, the exposure to high LET radiation from radium and radon progeny leads to difficulties in applying these risk estimates more generally. As a consequence, the principal source of epidemiological information underlying radiological protection remains the Japanese atomic bomb survivors, supported by findings from studies of patients exposed to high doses for medical reasons.

A number of assumptions have to be made when applying radiation risk models derived from the experience of the Japanese atomic bomb survivors to conditions of occupational exposure. The Japanese atomic bomb survivors were a general population, malnourished because of wartime conditions, who were exposed to an acute burst of (mainly low LET) radiation from the weapons, and who had to survive the difficult conditions that followed the bombings. Risk estimates derived from this population are applied to working adults of various races who are generally exposed at low dose rates over a protracted period and who may also be exposed to internally deposited radionuclides and other occupational agents. The assumptions made in generalizing from the experience of the Japanese atomic bomb survivors to the conditions of exposure usually encountered occupationally are made for the purposes of radiological protection and are considered to be conservative. Nonetheless, in the 1970s suggestions were made that the risk to radiation workers was being underestimated and it was thought prudent to study directly groups of nuclear industry workers to check that the risk models underlying radiological protection were broadly correct. However, as noted above, if risk coefficients derived from the study of workers are to have the necessary accuracy to allow a meaningful comparison to be made with predictions from standard risk models, then these studies must have sufficient statistical power. This means that large numbers of workers must be followed over a long time period to allow sufficient numbers of deaths or cancer registrations to be included. Further, cumulative occupational doses must be assessed with reasonable accuracy and a range of doses is required with sufficient workers having accumulated relatively high doses so that a dose–response analysis is a reasonable proposition.

With the above in mind, it is clear that it is desirable to conduct studies of combined workforces, and this has been done at a national level in Canada, the UK and the USA [1, 2]. The most recent analysis of the National Registry for Radiation Workers in the UK [13] has produced excess relative risk coefficients of 2.55 (90% confidence interval[1] (CI): -0.03, 7.2) Sv^{-1} for leukaemia (excluding chronic lymphocytic leukaemia) and 0.09 (90% CI: -0.28, 0.52) Sv^{-1} for solid tumours. These risk estimates are compatible with the equivalent coefficients from the Japanese atomic bomb survivors: 2.15 (90% CI: 0.43, 4.7) Sv^{-1} for leukaemia and 0.24 (90% CI: 0.12, 0.37) Sv^{-1} for solid tumours, respectively. The compatibility of these risk coefficients is reassuring for radiological protection.

The future of epidemiological studies of those exposed occupationally to ionizing radiation must lie in large studies of radiation workers as the means of achieving reasonable accuracy of risk estimates. IARC is currently extending its international study of radiation workers from the workforces in the three countries that were the subject of its findings published in 1995 [12] to workers in 17 countries that will encompass over 600 000 individuals [14]. It is important in large collaborative studies such as this to account properly for sources of uncertainty, particularly in dose records, and to ensure that the collection and collation of data follow a common protocol. The IARC study has paid particular attention to these issues [14].

Potentially, the international collaborative IARC study could produce risk estimates of an accuracy comparable to that currently available from the Japanese atomic bomb survivor studies, especially with the inclusion of the highly exposed workers from the former USSR. This study may well achieve the goal of providing a meaningful cross-check of the risk models currently underlying radiological protection, and, possibly, of producing risk coefficients that are sufficiently accurate as to have predictive value in their own right.

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[1] The figures in parentheses refer to the upper and lower limits at a confidence interval of 90%.

4. CONCLUSIONS

Epidemiological studies of past occupational exposures, in particular of luminizers to radium and of hard rock miners to radon and its progeny, have contributed materially to the derivation of radiation risk estimates for specific sites of cancer. Large studies of radiation workers, especially nuclear industry workers, have the potential to produce risk coefficients that will allow direct comparison with the predictions of the standard models upon which radiological protection is based. These risk coefficients may eventually provide a basis for the setting of radiological protection standards, one that does not rely upon the generalizations from the Japanese atomic bomb survivors that are currently required. Certainly, the risk estimates from large worker studies will allow a direct check on the accuracy of a number of assumptions (such as the dose and dose rate effectiveness factor, to name but two).

Large epidemiological studies require international collaboration and the co-operation of workers and employers. If the goodwill that currently exists in the IARC international study continues, then the prospects are good for obtaining accurate risk estimates derived directly from radiation workers. Since the limitation of the risk to radiation workers is one of the principal objectives of the present regime of radiological protection, it is to be hoped that this international co-operation will continue and flourish.

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OCCUPATIONAL HARM ATTRIBUTED TO IONIZING RADIATION EXPOSURE
An overview of current compensation schemes and dose reconstruction techniques

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Abstract

Compensation schemes for occupational radiation induced health afflictions vary considerably from nation to nation throughout the world. This paper reviews the readily available information on compensation schemes for various countries and focuses on whether such schemes for occupational radiation exposure induced health effects are covered by the specific circumstances of the work or under a general workers compensation regime. Conclusions lead to issues of what parameters make for an efficient, fair, timely and circumstance dependent occupational radiation compensation scheme.

1. INTRODUCTION

With increasing public awareness of the presumed risk to health attributable to the use of nuclear energy, there is also an increasing interest in the approaches (schemes) used to recognize the association of occupational exposure to radiation and adverse health outcomes in order to compensate fairly those so harmed. Furthermore, it is of interest to understand whether a compensation scheme is general in nature and applies to all workers regardless of the nature of work performed or specifically designed and applicable to radiation exposed workers. To review and evaluate various compensation schemes, the absence or application of several key concepts must be examined. These concepts include: the *types of affliction* compensated (injury versus illness, deterministic versus stochastic effects, permanent physical versus mental injury); the *criteria for compensation* (proof of causal relationship (existence of risk and/or proof of exposure), probability of causation versus presumptive, type and extent of radiation dose versus exceeded threshold dose); and, the *type of compensation* awarded (medical expense coverage, lump sum fixed amount, economic loss based on degree of wage loss or years of life lost, pain and suffering allowance, protection of employment contract).

The following discussion provides an overview of the current compensation schemes and the radiation dose reconstruction techniques utilized for cancer related claims.

2. DISCUSSION

A most enlightening summary of compensation schemes relevant to occupational harm attributable to ionizing radiation exposures may be found in the document entitled Compensation Regimes Applicable to Radiation Workers in OECD/NEA Countries produced by the OECD Nuclear Energy Agency (OECD/NEA) [1]. This summary examines compensation schemes from 20 participating OECD/NEA countries and in general notes an absence of specific compensation regimes solely applicable to radiation workers. With the exceptions of the United Kingdom and the United States of America, radiation workers in OECD/NEA countries are typically subject to the general worker compensation regimes or national based social insurance. This summary review does not provide information on pertinent OECD/NEA Member countries that failed to provide such information, or information on non-OECD/NEA countries.

For countries where general compensation regimes or national based social insurance schemes are applied, there is considerable variation in the types of affliction compensated, criteria for the proof needed to achieve compensation and type of compensation awarded. In the Republic of Korea, nuclear fuel cycle workers are compensated under standards established by the nuclear operator and approved by the Minister of Science and Technology, yet the standards governing payment of award comply with provisions of the Industrial Accident Compensation Insurance Act (a legislated general worker social insurance coverage). Australia, the Czech Republic, France, Germany, Greece, Italy, Japan, Luxembourg, Norway, Spain, Sweden and Switzerland use a general worker's compensation programme scheme or social insurance regimes to provide coverage for radiation related injuries and illnesses where the worker must 'establish' that permanent physical injury or illness occurred as a result of the work performed. France has perhaps one of the oldest (1898) general worker compensation schemes, one which has been amended several times to provide comprehensive coverage for deterministic and stochastic effects resulting from radiation exposure in various occupationally exposed workers (i.e. nuclear fuel cycle personnel, hospital and laboratory employees, miners and general industry workers). Denmark, Finland, Hungary and Iceland have no specific compensation scheme provisions for radiation workers. In Turkey, the Turkish Atomic Energy Authority has established an occupational radiation compensation scheme that requires a dose threshold (annual equivalent dose limits) basis be exceeded before additional health vacation or early retirement benefits would be awarded.

As regards countries with compensation schemes specific to radiation workers, these schemes vary in types of affliction compensated, criteria for compensation, type and extent of award coverage, and whether the scheme is nationally legislated or independently directed. In the UK, the Compensation Scheme for Radiation Linked Diseases (CSRLD) has provided compensation to workers exposed to ionizing radiation since 1982 [2]. The CSRLD is not a legislated legally binding scheme; participation is voluntary and supported by labour unions and nuclear energy employers. While it provides an alternative to legal recourse, the CSRLD does not prohibit a claimant from taking legal action unless the claimant has received an award under the scheme. In the USA, the Federal Government has intervened to provide federal compensation programmes with broad inter-state involvement in the case where large classes of radiation exposed workers are affected. For example, under the Radiation Exposure Compensation Act of 1984 (RECA), uranium miners, millers and individuals who transport ore are compensated if they are diagnosed with one of 22 'presumptive' cancers and meet specific time-frame requirements. Also in the USA, military veterans exposed to atmospheric nuclear detonations and tests are compensated once they provide diagnosis of a presumptive disease (cancer), proof that they were actually present during specified nuclear detonations and that they meet specific time-frame requirements. Lastly, the US Congress passed the Energy Employees Occupational Illness Compensation Program Act (EEOICPA) which compensates workers who were involved in the research development, testing and fabrication of nuclear weapons [3]. For cancer related claims, the EEOICPA scheme utilizes dose reconstruction methodologies which provide annual estimates of radiation dose for each claimant which are then used to determine the probability that the dose caused the specific cancer [4–6]. In the Russian Federation, a special compensation scheme legislated under the National Russian Federal Law on Social Protection has been initiated to provide coverage for emergency response workers exposed to, and affected by, radiation from the Chernobyl catastrophe [7]. All of these occupational radiation exposure related schemes are homogeneous in that they share the common trait of 'no fault basis' and require proof of eligibility in that the nature of the work resulted in the disease acquired. Each of these schemes employs various and different key concepts for determining a claimant's right to compensation.

With regard to type(s) of affliction compensated under these schemes, the CSRLD in the UK covers most cancers (Hodgkin's disease, chronic lymphatic leukaemia, hairy cell leukaemia and malignant melanoma of the skin excluded) and cataract of the eye. As previously noted, in the USA, RECA compensates for the stochastic effect of 22 cancers, as does also the compensation programme for military veterans. For the veteran's programme, types of cancer other than the 22 presumptive ones, cataracts and non-malignant cancer require a dose reconstruction and probability of causation process. Within EEOICPA, all cancers other than chronic lymphocytic leukaemia are covered; deterministic effects are not compensated for under EEOICPA. In the Russian Federation, the Chernobyl ‘liquidators’ are compensated for acute (acute radiation syndrome and cataracts) and chronic (leukaemia and cancer) radiation induced effects as identified by the Public Health Ministry in a list of 21 diseases. Disabling effects from the Chernobyl catastrophe considered in this list include not only acute radiation syndrome, leukaemia and cancer, but also stress, change of life-style patterns and other social problems as well.

While all of these radiation worker specific schemes require proof of eligibility (employment as a radiation worker, exposure to radiation specific to the scheme and diagnosis of a covered health effect), the criteria for compensation under these schemes vary in application. The CSRLD utilizes a probability of causation determination to quantify the degree of confidence that a particular cancer was caused by the radiation exposure experienced. The probability estimate is used to determine the level of compensation as described below. The calculation of probability is accomplished by using dose histories provided by the employer, which are reviewed and confirmed by the claimant’s respective trade union, and modified relative risk models accounting for uncertainty while giving the benefit of the doubt to the claimant. If agreement on dose history is not achieved between the employer and the trade union, the claimant may approach an independent expert panel or seek legal recourse.

In the USA, under the veteran’s programme and EEOICPA for non-presumptive cancers, a dose reconstruction process using all available information on radiation exposure potential and established health physics methods provides annual reconstructed dose estimates. These dose estimates are then used in probability of causation, cancer specific risk models. These US approaches account for uncertainty in type and quantity of radiation dose, and uncertainty associated with the scientific basis for a given risk model. The US risk models are based on the 1985 National Cancer Institute’s Radio-epidemiological Tables as modified for the respective scheme. Full benefit of the doubt is afforded to the claimant in how all uncertainty is handled and by the fact that probability of causation is set at the 50% probability level of the 99th percentile (upper bound of uncertainty). In the Russian Federation, manifestation of the covered health effect is sufficient for compensation of Chernobyl liquidators as determined by the Medical Commission; probability of causation is not used to determine degree of association of radiation exposure and health effect. Also, liquidator compensation is not dependent on recorded, assigned or reconstructed dose but on general information and data regarding working conditions (work performed, work location, time spent in work location). Dose reconstruction efforts on Chernobyl liquidators are performed as a critical component of research studies under way to better understand the health impact of the catastrophe.

Lastly, these compensation schemes specific to radiation workers vary considerably in type of compensation awarded. As indicated previously, the CSRLD awards payments are based on a sliding scale using the calculated probability estimate to determine whether full, partial, or no payment is to be made. A ‘quantum’ determination of compensation amount (full sum) is comparable to that in a successful legal claim and the appropriate fraction applied to make the award with consideration given to claim specific factors (loss of earnings, pain and suffering, number of dependant children).

In the USA, RECA and EEOICPA provide a lump sum compensation of $150 000 and the veteran’s programme compensates on the degree of disability or harm. The veteran’s programme and EEOICPA also provide prospective medical benefits compensation for disabled claimants alive at the time of award. All Russian liquidators are compensated with a lifetime pension. For those found to be disabled with one or more of the 21 recognized diseases, their pension compensation is augmented by one of three levels of disability (1000, 2500, or 5000 roubles). Reportedly, all liquidators are further compensated by tax exemption, reduction of rent and communal services charges, free provision of medical services and free public transportation.

3. CONCLUSION

The majority of compensation schemes around the world which have been reviewed here do not have a specific focus on, nor are designed for, radiation workers; most schemes compensate health effects from radiation exposure under general, nationally legislated worker’s compensation or social insurance regimes. Three countries were found to have compensation schemes designed and applicable specifically for the health effects associated with occupational radiation exposure. However, these varied in the types of affliction covered, criteria for compensation, and the type and extent of compensation awarded. There was similarity across the three countries’ schemes with regard to ‘no fault’ ascribed to worker or employer and ‘proof of eligibility’ (presence in radiation work environment and diagnosed disease). Major differences across the schemes involve the manner in which causation is determined, the existence or not of lists or tables used to define compensatable afflictions presumed to be occupational in origin, and the type and level of compensation awarded. At issue is what parameters make for an efficient, fair, timely and circumstance dependent occupational radiation compensation scheme. Should occupational radiation compensation be designed and applicable to the circumstances of the work, and if so, should there be global compensation concepts or guidelines for a nation to consider in its scheme? Or, should compensation for radiation induced afflictions be covered under nationally legislated general worker’s compensation or social insurance regimes, and if so, what global compensation concepts or guidelines should be available for consideration and use?

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TOPICAL SESSION 9

DISCUSSION

I.A. GOUSSEV: In the Russian Federation there are two groups of 'recovery operators'. The first group consists of nuclear industry professionals who take part in recovery operations following radiation incidents and accidents (and who may have participated in such operations following the Chernobyl accident). The second group consists of people who were just 'liquidators' after the Chernobyl accident.

The nuclear industry professionals undergo annual medical checks throughout their working lives and detailed dosimetric records are kept on them, records which are evaluated by a special medical council run by the well-known radiobiologist A. Guskova. The Chernobyl liquidators are not under that kind of medical surveillance.

Of the nuclear industry professionals who have submitted claims for compensation for ionizing radiation linked afflictions, fewer than 10% have received a positive response.

R.P. BRADLEY: Could R. Wakeford say something about epidemiological studies of non-fatal cancer incidence and non-cancer mortality attributable to radiation exposure?

R. WAKEFORD: A report on large scale studies of non-fatal cancers among Japanese atomic bomb survivors was published in 1994 by UNSCEAR. The studies have continued since then and I believe that an update of the report is due to be published soon.

The ability to study non-fatal cancer incidence, as opposed to cancer mortality, within a given country depends on whether that country has a national cancer registry. The UK has had one since 1971, but many countries do not. In our workforce studies we take non-fatal cancer incidence into account since there is a high probability of survival with some cancers (for example, skin cancer and thyroid cancer), so that cancer mortality numbers give only an incomplete picture.

As regards non-cancer mortality, we are considering it in our workforce studies, but the numbers are difficult to interpret. There seems to be a non-cancer mortality excess due to radiation exposure among the Japanese atomic bomb survivors, with deaths due mainly to cardiovascular diseases, but it is not clear whether the various fatal diseases in question are due to tissue damage caused by high radiation doses received in 1945 or to some underlying stochastic cause.

H.-H. LANDFERMANN: The Japanese atomic bomb survivors experienced a very short radiation exposure and the Mayak workers experienced a very long one. What are the dose reduction factors for those two groups?

R. WAKEFORD: I don't think the Mayak worker studies are sufficiently advanced for your question to be answered, since, in order to answer it, one needs a reasonably accurate estimate of either the excess relative risk or the excess absolute risk per unit dose.

If one compares the Japanese atomic bomb survivor studies with the latest UK workforce study, one sees slopes which are compatible with a DDREF of two for solid tumours. However, the slopes are also compatible with a DDREF of one and a wide range of other values. It will be possible to answer your question only after enough epidemiological studies of enough statistical power have been conducted.

J. VAN DER STEEN: Regarding the study of the International Agency for Research on Cancer (IARC) of radiation workers in 17 countries, do the life expectancy and the background cancer incidence and mortality rates not differ from one country to another?

R. WAKEFORD: Yes, they do. That is why particular care must be taken when one is merging data sets. However, there are fairly sophisticated statistical techniques for data set merging.

V. CHUMAK: The Chernobyl liquidators constitute a cohort that is fairly comparable with the radiation worker cohorts currently the subjects of epidemiological studies and most of them are traceable. They are therefore also the subjects of epidemiological studies.

For example, IARC is conducting a study on leukaemia among Russian and Belorussian liquidators and there is a US National Cancer Institute funded study under way on leukaemia among Ukrainian liquidators. The latter is a case control study based on a cohort of 100 000 persons and its statistical power is expected to be considerable.

We have just completed a study on cataracts in a cohort of 9000 persons. Our incidence and prevalence findings suggest that there is no dose threshold as far as the generation of cataracts is concerned.

D.J. BENINSON: There have just been a couple of references to ‘statistical power’. In that connection, I would recall that for a given level of statistical power the dose squared times the number of people in the epidemiological study sample is fairly constant. Hence, if you reduce the dose by a factor of ten, you must, all other things being equal, increase the number of people in the sample by a factor of 100 in order to maintain the statistical power. This is often overlooked.

L. MJÖNES: Regarding what R. Wakeford said about the influence of cigarette smoking on the risk associated with exposure to radon, I would recall that the ICRP dose conversion convention was calculated from risk figures arrived at through epidemiological studies and that most of the miners covered in those studies were smokers. Since there is synergy between smoking and radon exposure as regards lung cancer, one could say that the doses and therefore the risks calculated with the dose conversion convention are overestimates.

R.T. LOUW: For the past seven years, we have been conducting a biological dosimetry programme using the FISH method, and we recently broadened the programme to include the study of deviations in the B53 gene as an early indicator of leukaemia. We are now broadening the programme further to include work on the use of antibiotics in countering the effects of radiation on cells and efforts to identify workers of above average radiosensitivity. We hope that the results of the programme will be of practical value in due course.

F. DARROUDI: Biological dosimetry is potentially very important for occupational radiation protection, and my laboratory and a number of other laboratories have developed some useful techniques for application in, for example, dose reconstruction.

D.J. BENINSON: There is quite a spread of opinions about the practical value of biological dosimetry in occupational radiation protection, but the subject certainly deserves to be thoroughly examined.

A. FUČIĆ: We now have biological dosimetry methods which enable us to determine with a high degree of accuracy the doses resulting from recent exposures and from exposures which occurred as much as 40 years ago, so that we can reliably say that a given person who is not exhibiting symptoms is, say, ten times as likely to develop a cancer as the average person.

Occupational radiation doses have been declining and we should be very pleased about that, but there are many workers today in their 50s who received high doses during the 1970s and 1980s and are, as a consequence, going to develop a cancer during the next 10–20 years.

G.G. EIGENWILLIG: In Germany, only compensation claims for primary cancers attributable to ionizing radiation are accepted for consideration, not claims for secondary cancers. The authors of paper IAEA-CN-91/86, however, mention an innovation in the USA whereby claims for secondary cancers are accepted for consideration when the primary cancer site cannot be identified in the available records. Would L.J. Elliott care to elaborate on that point?

L.J. ELLIOTT: In the USA, we have elderly claimants who were involved in the US nuclear weapons programme as far back as the mid-1940s. Many of their former colleagues have died and in the death certificates we have often found a secondary cancer given as the cause of death. In our dose reconstruction efforts, we try to reconstruct the dose to the target organ. Rather than using just secondary cancer data, we have therefore adopted an approach whereby, with the help of cancer registry information, we try to determine the likely primary cancer, an approach which, in our view, is favourable to the claimant.

G.A.M. WEBB: It is important that compensation schemes be, as far as possible, science and evidence based. Consequently, as so few countries already have compensation schemes, I think it would be helpful if the IAEA, ILO and other relevant organizations developed general guidelines for their establishment.

C.J. HUYSKENS: In order that a compensation claim may be accepted for consideration in the USA, is it necessary that the claimant assert that regulatory limits were exceeded?

L.J. ELLIOTT: No, it is not.

E. AMARAL: What is the situation in the USA regarding compensation for cancers not related to ionizing radiation?

L.J. ELLIOTT: With a cancer not closely associated with ionizing radiation, it is necessary to demonstrate exposure to a very high dose in order to obtain a probability of causation estimate that will trigger a compensation award.

G. SALLIT: Besides the Compensation Scheme for Radiation Linked Diseases, mentioned by L.J. Elliott in his oral presentation, there is, in the UK, a compensation scheme for military veterans who were involved in the nuclear weapons tests carried out by the UK. The scheme is administered by the Ministry of Defence's War Pensions Agency, which looks into a whole range of possible initiators of a particular disease. The scheme is a controversial one, however, and the UK nuclear weapons test veterans have lodged a complaint against the Ministry of Defence with the European Court of Human Rights.

C.J. HUYSKENS: Is not great care needed when trying to interpret excess relative risk information from epidemiological studies and to convert it into figures easily applicable in calculating a probability for a single individual?

R. WAKEFORD: It is a question of how one transfers risk across populations. For many forms of cancer, the transfer of the relative risk is better than the transfer of the absolute risk. In the UK, this is recognized as an uncertainty and taken into account by means of 'generosity' factors. The result is not perfect, but if it is accepted as equitable by claimants and potential claimants, the objective has been achieved.

L.J. ELLIOTT: It is recognized as an uncertainty in the USA as well. Epidemiological studies are population based studies and transferring a population based set of risk estimates to an individual is difficult at best and perhaps never very meaningful.

In this connection, we are anxiously awaiting the report of the Committee on Health Risks from Exposure to Low Levels of Ionizing Radiation (BEIR[1] VII).

[1] Committee on the Biological Effects of Ionizing Radiation.

ROUND TABLE 1

IS THE CO-OPERATION BETWEEN REGULATORS, EMPLOYERS AND WORKERS ACHIEVING OPTIMUM OCCUPATIONAL RADIATION PROTECTION?

Chairperson: **W. Bines** (United Kingdom)

Round Table Members: **E. Amaral** (Brazil)
J. Billard (United Kingdom)
J. Ishida (Japan)
J. Lochard (France)

Scientific Secretary: **M. Gustafsson** (IAEA)

Round Table Presentation

VIEWS OF THE REGULATORS

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It is important to remember what the concept and objective of optimization are and the role of dose constraints. In relation to exposures from any particular source within a practice, radiation protection shall be optimized so that the magnitude of individual doses, except for therapeutic medical exposures, the number of exposed people and the likelihood of incurring exposures will all be kept 'as low as reasonably achievable' (ALARA), economic and social factors being taken into account, within the restriction that the dose to individuals delivered by the source be subject to dose constraints.

Dose constraints and dose limits to occupational exposures are necessary since the workers are not the direct beneficiaries of the exposures and the optimization procedures based on collective doses could result in inequities. The dose constraint has the secondary function of ensuring that the sum of the doses that an individual received from different practices to which the individual can be exposed does not exceed the dose limit.

Before discussing co-operation, it is fundamental to provide a description of the role and responsibilities of the regulatory authority, employers and workers.

The role and responsibilities of the regulatory authority in establishing regulations, granting authorizations, undertaking inspections, ensuring enforcement, and dealing with accidents and emergencies are set by the national legislation.

To achieve this objective, the licensee is required to use, to the extent practicable, procedures and engineering controls that are based upon sound radiation protection and safety principles.

The regulations establish that the licensees and employers of workers who are engaged in activities that involve or could involve occupational exposure shall be responsible for the protection of these workers against any occupational exposure that is not excluded from regulatory control. They shall ensure that:

(a) Occupational exposures are limited and radiation protection is optimized;
(b) Arrangements are made to facilitate consultation and co-operation with workers, through their representatives where appropriate, about measures which are

needed to achieve adequate radiation safety by an effective implementation of the regulations.

The last requirement establishes/recognizes that co-operation between the principal parties (licensee and employer) and the workers is necessary to achieve adequate radiation protection (optimization). The regulations establish that the licensees, in co-operation with employers if appropriate, shall establish, maintain and keep under review a programme for the monitoring of the workplace, commensurate with the nature of, and the risks associated with, the source.

Co-operation among licensee, employer and workers can/should be required by regulators, as noted before. However, an important aspect of the legislation is that the regulators' enforcement applies to the licensee and not to the employers. The rules and demands can be directed to the licensee and employers but only the licensees are under the direct control of the regulators.

However, how can the regulator co-operate regarding the optimization of occupational radiation protection? The regulatory authority shall be established (by legislation) as a body that is effectively independent of the licensees and the designers and constructors of the radiation sources used in practices. Therefore, co-operation from the regulators may be difficult to apply. However, there are some areas with good examples (e.g. in Brazil) of co-operation with:

(a) Professional bodies, such as with the Brazilian Association for Medical Physics and the Brazilian College for Radiology, in order to verify perso-nal qualification and accreditation and to set up continuous education programmes.
(b) Suppliers, factories and users to help prepare practice specific regulations.
(c) Authorized/accredited individual monitoring laboratories to help on the maintenance of a national dose history occupational database.
(d) Employers and radiation protection officers to determine reasons for the indication or evidence of dose increase trends and procedures required to reach ALARA. This was done recently for gammagraphy professionals.

However, there is still much more to do and the authors pose additional questions:

(a) Dose constraints for specific practices shall be established on the basis of well-managed radiation protection. Have the regulatory authorities/employers done it? Not in Brazil.
(b) To observe the dose limits it is necessary to sum all occupational exposures that a single worker can be exposed to. Who is responsible for verifying the dose summation?
(c) The occupational dose due to technologically enhanced naturally occuring radioactive material is not optimized and sometimes above the dose limit. How

to deal with this new problem? In the case where the practice started operation before regulations, does responsibility for the mitigation actions lie with the employer or the regulator? In Brazil, employers are being helped to evaluate the problem and workshops organized.

(d) Is it also necessary to have co-operation between licensees and manufacturers? Yes. This shall be requested to the licensees by the regulators. However, this is often difficult.

Finally, for employers and workers it is important to know the identity of the regulator. Who is the regulator?

(a) If it is the case that the ministry of health is the regulator for medical exposures, is the labour ministry similarly the regulator for occupational exposures? In the same way, is the ministry of environment the regulator for public exposure?

(b) What is the role of the nuclear authority? In most countries it has far more prestige and knowledge in dealing with all exposure categories.

In summary, there should be a clear definition of actions and co-operation among all regulators to optimize radiation protection.

Round Table Presentation

VIEWS OF THE EMPLOYERS

J. Ishida
Japan Nuclear Cycle Development Institute,
Tokaimura, Ibaraki,
Japan

The employer shall establish and maintain a safety management system, which is a part of the overall management system that facilitates the management of the occupational health and safety risks associated with the business of the organization. In addition to meeting its legal responsibilities, the employer should aim to improve its occupational health and safety performance, and its safety management system, effectively and efficiently, to meet changing business and regulatory needs. Occupational radiation protection is also a part of its activities.

The concept of 'as low as reasonably achievable' (ALARA) presumes that any increment of radiation dose may produce a proportionate incremental risk, and that all radiation doses shall be kept ALARA, taking into account social and economic factors.

Up to now, by implementing various activities in accordance with the principle of ALARA, employers have been minimizing the exposure dose of plant workers. Owing to improvements in hardware and administrative control, the exposure dose of workers has followed a remarkable downward trend, and now the number of workers exceeding 20 mSv/a is nearly zero.

By implementing more thorough radiation protection and safety programmes, as well as by promoting safety consciousness among individual workers, the employers are continuing their efforts, respecting ALARA, to prevent workers from being exposed to radiation unnecessarily. As a consequence, the average individual dose of workers has dropped to 1 mSv/a or so.

There may no longer be a discernible decrease in doses received at most of nuclear facilities. Even at these very low exposure levels, does the dose control remain a key priority? Here, the author poses two questions:

(1) How much room is there for further reduction of the exposure dose of workers?
(2) Is it possible to set an exclusion level, in the case where the exposure dose is less than the natural level, below which consideration of ALARA or optimization is not required?

In any case, the optimization and dose limitation principles have been applied for minimizing the exposure dose of workers.

In case the dose limits are exceeded, proper countermeasures should be taken to reduce the exposure dose. Setting guidelines and standards is very effective when considering the level of exposure for the control and support of work implementations.

Whereas the concept of dose limitations is easy to understand, the optimization process often involves a wide range of parameters and leads to complex mechanisms and therefore the judgement based on the analysis is not always connected with the final decision. The optimization that will be done is based on the level of residual risk that all interested parties accept as a realistic figure. If the residual risk is important, it has to be taken into account for legislation. However, actually it does not fit in law because, as legally binding targets, its quantities are too small to enshrine in law and are too changeable, depending as they do on the societal situation.

Rather than achieving optimization, the author would describe it in a slightly different way, namely, that the safety management system, which is aiming for the *continual improvement* in overall occupational health and safety performances, should be established in line with the employer's safety policy.

Continual improvement is important, which is to say that our activities in radiation protection comprise a continual process for minimizing for the exposure dose of workers by considering our own operating experience and that of others. The author considers the latest performance of other organizations to be informative. Good performance is a good indicator when an employer sets achievement as its goal.

Therefore, information/experience exchange between regulators, operators and professionals through the Information System on Occupational Exposure (ISOE), the World Association of Nuclear Operators (WANO), the International Network for Safety Assurance of Fuel Cycle Industries (INSAF), the Nuclear Safety network (NS net)[1], etc., is workable. For example, the ISOE/WANO introduces the average annual dose per unit and the average individual dose at reactors throughout the world. Good results at one reactor would be the target of the other reactors. These data are very persuasive because the data shown are not paper plans but actual figures. The member organizations can promote their own safety level by working towards their objectives. Of course, after setting the goals they need to consider how to reach the targets by collecting information from the good plant.

At this point the author would like to introduce some activities of the network system in Japan. One is the NS net which is a domestic networking organization established in order to promote the widespread adoption of improved safety measures in the nuclear industry and based on the lessons learned from the 1999 criticality accident at the uranium processing facility in Tokaimura. The main activities are the safety 'caravan' and the peer review and the results of these are passed to all member

[1] See http://www.nsnet.gr.jp/english/activity/activity_index.html.

organizations of NS net. Good performance serves as a good reference at similar facilities.

The other activity concerns INSAF, which was also established to serve a similar purpose as NS net after the criticality accident at Tokaimura, the difference being that the members of NS net are only domestic organizations whereas INSAF includes nuclear industries from overseas among its members.

The author believes that these kinds of activities (for setting higher goals of continuous improvements) need to be enhanced.

As regards the relation between regulators and organizations, fundamentally, an employer is responsible for its own safety. It is not easy for the regulator, an 'outsider', to understand completely what work the employer is doing. In order to make the regulation system effective, the regulated side also needs to collaborate with the regulator. However, when this develops, a regulator will be dependent on the employer being regulated. A regulator's knowledge will be manipulated using the information that the regulated side offers. It is important for a regulator to check if an employer has a good enough system to advance work safely, although it does not need to consider each step of work performed by an employer as being subject to regulation.

The regulator no longer needs to trigger 'alarm bells' in order to pull down the dose limits. Setting the dose limits may be an important role of regulators, but frequent law changes will throw us into confusion.

With regard to the relationship between employers and workers, an employer and its workers are often said to form the 'two wheels of a cart'. The implied meaning here is that the two wheels do not always turn in synchrony. The analogy ought to be interpreted to mean that the employer can remain healthy and vigorous if the distance between the wheels or their respective rotation speeds are adjustable as needed to create healthy tension, thereby improving their collaborative relationship.

An employer should place emphasis on a systematic programme of education and training of workers to enable them to carry out their designated functions.

The activities of NS net are discussed in the following paragraphs.

Peer Review: Teams composed of member experts will conduct mutual evaluation of nuclear safety related activities implemented by each member facility. Experts will issue evaluation reports after visiting the facilities, inspecting the documents, conducting interviews and thoroughly discussing the facilities.

Seminars: Seminars are to be conducted by outside experts as part of an effort to improve safety and ethics in the nuclear power industry. The seminars are aimed at all levels of members, including managers and supervisors.

Safety caravan: Visits to member business locations will be arranged in order to increase safety awareness and to share and improve safety culture among members. These visits will involve safety lectures, presentations of safety training materials and exchange of views with site personnel.

Round Table Presentation

VIEWS OF THE WORKERS

J. Billard
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In answer to the question, “Is the co-operation between regulators, employers and workers achieving optimum occupational radiation protection?”, the basic answer is “yes” or “it should do” or “it may do”. There are a number of problems which might prevent an optimum solution. Co-operation with workers always provides a better solution than the alternative, so there is a joint interest to protect the workers and the employer in the conduct of its business.

1. RISK TO WORKERS

As the nuclear industry has matured, workers are now regularly required to keep to just a fraction of the legal authorized limit. In addition, where higher doses are possible careful use of worker rotation will reduce the risk. However, it is interesting to note that workers undertaking industrial radiography can incur high doses because they may be poorly supervised.

There are also hazards in decommissioning experimental reactors where, after a period of long operation, records or the memory of operators may be incomplete or not available. There is also a risk in reprocessing and handling the waste stream where exit routes previously thought to be available have been closed because of developing environmental concerns.

In all this, trust is needed between workers and employing organizations to provide the best protection.

2. OPEN APPROACH

A blame culture must be avoided and non-culpable reporting must be introduced to pick up poor practice or to address the concerns of workers. Such a system may be effective where there is a strong worker organization and where the organizations themselves have a culture of open reporting.

However, current experience in the United Kingdom is witnessing the break-up of large organizations and the introduction of contracts and sub-contracts and far greater commercialization in the nuclear industry. This may lead to an organization being required to take action to give maximum worker protection which otherwise would not be appropriate in a commercial environment. Consequently, it is essential that plant management must have an obligation to control its contractors. The best way of achieving this is by ensuring management's co-operation and not by diktat.

Furthermore, contractors may be unwilling to admit to errors in order to avoid breach of contract claims and may find it more difficult to accept the 'no blame' reporting system already referred to. Therefore, an employer can be put in the position of deciding whether to protect an employee or to placate a regulator or public perception.

Whilst the author's experience of the UK industry is that it operates with commendable openness, with the regulator encouraging honest communication, there may still be effects with regard to the non-culpable reporting system or to an individual worried about their health. The effect of stress on a worker during dose related investigations must not be overlooked. Therefore, it is necessary to see that organizations, unions, employers and contractors work together and that they be regarded as part of the same 'team'. Optimum protection ('as low as reasonably achievable') may work best where there is a short 'distance' between management and workforce.

3. RADIOLOGICAL PROTECTION VERSUS SAFETY PROTECTION

There may be a conflict here. The standard of hazard assessment may be difficult to assess if the task may incur injury or death within a period of fifty years. Therefore, it is considered essential that the experts drawing up radiological protection regulations be made aware of the need to consult with those workers directly involved in a potential radiation hazard.

It is also essential that if regulators report on the safety of nuclear installations they consult with employee representatives as well as the management. This can sometimes be forgotten, however inadvertently.

An absence of interaction between employers, regulators and representatives can lead to actions being taken that are poorly understood by the workforce and therefore poorly implemented. Even if there is a much better safety culture now than in the 1950s or 1960s, it can still be difficult to convince workers to protect themselves against a hazard they can neither see nor feel. The best solutions for optimum radiation protection may be lost because of the lack of the worker's contribution. Therefore, the worker must be brought into the picture.

4. CONCLUSION

Co-operation is bound to provide better protection and doses generally are being reduced. Establishing good trust with workers and an open approach to their interests remain essential. The commercial approach to nuclear handling provides a challenge to co-operation. In the end, organized labour may have to depend on the regulators to ensure full worker participation.

Round Table Presentation

VIEWS OF THE RADIATION PROTECTION PROFESSIONALS

J. Lochard
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As has already been mentioned, the ‘as low as reasonably achievable’ (ALARA) principle is the cornerstone of modern radiation protection. Beyond the limitation principle, which ensures basic protection of individuals, ALARA is a pragmatic process of applying, in a responsible way, the precautionary principle which logically ensues from the no threshold assumption for low doses.

What is the present situation as far as the practical implementation of ALARA is concerned? It is everywhere recognized that the important improvement in the protection of workers that can be observed over the last twenty years has largely resulted from the generalization of the ALARA culture in most organizations. Whether the implemented ALARA processes were highly formalized or more reliant on common sense is a secondary aspect. The key lesson of the last decade is that it is less difficult to start with an ALARA approach in an organization than it is to maintain its effectiveness over a long period of time. How to ensure a continuous improvement in protection, taking into account the prevailing circumstances? This is where the present challenge lies and this is also where the so-called ‘stakeholder involvement’ approach can play a key role. But what does stakeholder involvement actually mean?

First, it is important to recall that stakeholder involvement is not an end in itself, nor a new way or a revamping of the traditional communication policy. Stakeholder involvement means a process through which involved parties are actively participating in the decision framing and decision making processes that are related to the protection levels and which are finally implemented at the design and operation stages of installations. There are two objectives: to construct effective and sustainable decisions at the design stage and to ensure the adoption of an on-going prudent and vigilant attitude in the routine management of the situations. It is also clear that in this process, the role of the workers is crucial as this is the group which is directly exposed and its level of exposure is largely linked to the behaviour of each of its members and to the various protective actions that have been implemented to control the situations in which they are involved. Because of this asymmetric position, workers deserve particular attention in the stakeholder involvement process.

Why involve all parties in the ALARA procedure? There are many good reasons for this, for example to:

(a) Take into account more effectively the characteristics of each exposure context and the expectations of the concerned parties,
(b) Ensure the adherence of each party to the decisions and to maintain the necessary vigilance over time,
(c) Identify and adopt more cost effective protection actions,
(d) Improve social trust between involved parties and confidence in the technical and organizational solutions that have been adopted,
(e) Promote accountability and autonomy of each concerned party.

This list is, of course, not restrictive. How to involve stakeholders in the ALARA procedure? Here again there is no unique approach. It is also worthwhile mentioning that experience with stakeholder involvement in occupational radiation protection is still very limited. There are involvement techniques that have been developed in various areas to structure the process of linking stakeholders to decision making; this ranges from classical consultation processes to more structured consensus building techniques, with or without the assistance of a third party. All of these techniques promote dialogue between parties, as well as clear and adequate rules of co-operation according to the context. The empowerment of the workforce, particularly through the development of a risk culture, is by far the most indispensable and unavoidable first step in the overall process. However, some key reflections still need to be developed here to respond to the following questions:

(a) How to ensure an equitable involvement of the workforce (or its representatives) which has lower resources, power and levels of education and information compared with the other parties?
(b) How can the availability and exchange of information influence the involvement of each party? How to develop a pluralistic expertise on conflicting issues?
(c) How to balance the interests of each party in the decision making process?
(d) How far is it appropriate to go to give workers a legal right to know and to interfere in the decision making process?

To conclude, it is obvious that co-operation between regulators, employers and workers is improving the implementation of the ALARA principle for occupational radiological protection. However, one must not be too naive. This co-operation is not evident. Each party has its own interests and they are far from being convergent, not forgetting that the general environment can rapidly evolve and impose external constraints. One can consider the impact of deregulation of the electricity market for example.

As a radiation protection professional, the author feels that a new period in the implementation of ALARA is beginning. The call for more stakeholder involvement is certainly a way to find a path for further improvements in the protection of workers without endangering the viability of the activities giving rise to exposure. This is also a means of gaining more sustainability in the control of exposure and of enhancing the responsibility of each party in the pursuit of this objective.

What role can the radiation protection professionals play in this process? Are they, after all, a specific stakeholder? Yes, if we consider that they represent the social interest of implementing good radiation protection whatever the situation is; good radiation protection meaning that it is based on scientific and technical knowledge and sound ethical principles. However, one must also keep in mind that these professionals are in most cases not fully independent of one another.

Whatever their future role, radiation protection professionals (and their societies) will have to follow the present stakeholder involvement trend. This will involve having an increased presence ‘on the spot’ to listen to the various points of view, to better understand the stakes of the involved parties, to participate in the definition of solutions and to help in their implementation. This will only be possible if, beyond their classical role, the radiation protection professional also becomes a mediator and a facilitator ready to integrate radiation protection into societal decisions.

ROUND TABLE 1

DISCUSSION

D.C.D. URQUHART: I should like to make three comments. In my opinion, although occupational radiation doses have been reduced substantially, there remain a number of challenges, for example, reducing the risk of radiation accidents not involving nuclear intallations, which still occur rather frequently.

With the increasingly ancient nuclear power plant fleet in the UK and the reduction in the limit for doses to members of the public from 5 mSv to 1 mSv, direct public exposures may well now account for a greater fraction of that dose limit than the fraction of the occupational dose limit accounted for by occupational exposures.

With regard to the relationship between regulators on the one hand, and employers, workers and members of the public on the other, the Health and Safety Executive in the UK has a duty to advise these stakeholders — in addition to regulating. In my opinion, two of the things which it could do better are helping to spread best practices and putting risks into some kind of real, tangible content.

R.W. ANDERSON: I should welcome views about whether the influence which stakeholders have on the decision making process is sufficient and whether the mechanisms for assessing the degree of satisfaction of stakeholders with their role are adequate.

W. BINES: That comment highlights the fact that there is no point in consulting people and ascertaining their views if you do not provide them later with feedback so that they can see what has been done in response to their views.

O. TUDOR: The views of stakeholders are taken into account in the UK. In the nuclear safety area, however, most regulations are developed at the international level, and it is more difficult to manage consultations with stakeholders at the international level than at the national — or workplace — level. In my experience, what you tend to get at the international level is simply discussions among regulators — a kind of second order stakeholder involvement that is not very satisfactory for stakeholders.

A.S. TSELA: Lobbying groups sometimes consider that a regulator — who, in their view, should be a watchdog — is ‘sleeping in the same bed with everybody’. To what extent should a regulator become involved in stakeholder debates?

W. BINES: In connection with that question, I would mention that in the UK it has frequently been put to the regulators that, as the general public does not have legal duties and hence does not have the responsibilities which employers have, its opinions should perhaps not be given as much weight.

J. BILLARD: Sometimes, in trying to protect the interests of workers, the workers' representatives have to approach the regulator directly and complain about the activities of the employer. The right to do so is enshrined in UK legislation and is something we consider important.

Our experience indicates that there is little love lost between the regulator and the operator, which is surprising; one would expect the operator to 'bend over backwards' in order to assist the regulator, but that does not always happen.

S. VAN DER WOUDE: We, as regulators, in South Africa have been grappling with the question of how far to become involved in stakeholder debates. Generally, stakeholders have reacted positively to our involvement in problem solving. That may be due to the fact that in South Africa the available expertise is rather limited, so that it is difficult for the regulators not to become involved. The result is that we have a tripartite consultation structure, with employers, workers and regulators all represented.

S.B. ELEGBA: From his round table presentation, I gather that J. Billard represents UK nuclear industry workers who are participating in a compensation scheme for radiation linked diseases. Are radiation workers outside the nuclear industry, for example, radiographers, covered by that scheme?

J. BILLARD: I would refer S.B. Elegba to contributed paper IAEA-CN-91/108, entitled The UK Compensation Scheme for Radiation-linked Diseases.

Under the UK Compensation Scheme for Radiation-linked Diseases, a distinction is made between cancers that have occurred naturally and cancers that have been caused by occupational exposure to ionizing radiation. The Scheme, which provides generous compensation to employees, was established with full co-operation between trade unions and employers, and it is proving to be an excellent alternative to litigation. In this connection I would mention that, because of the downward trend in radiation doses incurred, the number of successful compensation claims is declining.

R. COATES: Regarding A.S. Tsela's question, I believe that there is nothing wrong with regulators "sleeping in the same bed with everybody" if they do so openly and in a fairly formal manner, rather than behind the scenes.

Regarding S. van der Woude's subsequent comment, I would be interested to know how stakeholder satisfaction has been ascertained in South Africa.

S. VAN DER WOUDE: We commissioned a company that conducts customer satisfaction surveys to conduct a stakeholder satisfaction survey, helping it with the formulation of questions that would not be asked in a customer satisfaction survey.

We found that if operators did not agree with the standards applied or the approach adopted by the regulators, they tended simply to mark the regulators down. Overall, however, the findings were positive. We learned some valuable lessons and we are drawing on them in an endeavour to improve our relations with stakeholders.

While I have the floor, I should like to mention a problem that can arise when radiation protection in a given country falls within the remit of more than one regulatory body. At the international level, one body may work with the ILO, one with the IAEA and one with the WHO, and these international organizations employ somewhat differing terminologies which may themselves differ somewhat from the terminology employed by, say, the ICRP. I would welcome some terminological harmonization at the international level.

G.G. EIGENWILLIG: Co-operation among regulators, employers and workers is undoubtedly a good thing. In Germany, however, most of the expertise lies with the regulators and the employers, and the employers will not pay for extensive education and training not directly in support of the workers' job functions. As a result, the workers are unable to ask the right questions of the employers and the regulators. Moreover, the regulators are not required to consult the elected workers' representatives and keep them informed. I suspect that the situation is not very different in other countries.

W. BINES: G.G. Eigenwillig has made a very good point.

M. BOURGIGNON: With regard to occupational radiation protection in medicine, there are a number of societies representing professionals in the medical field that are very knowledgeable about radiation protection and with which we have been co-operating very successfully.

W. BINES: Yes, such professional societies can provide very useful input.

ROUND TABLE 2

HAS THE CONTINUED IMPROVEMENT IN RADIATION PROTECTION STANDARDS GONE FAR ENOUGH IN COMPARISON WITH STANDARDS FOR OTHER HAZARDS?

Chairperson: **A.C. McEwan** (New Zealand)

Round Table Members: **R. Coates** (United Kingdom)
G.P. de Beer (South Africa)
P. Deboodt (Belgium)

Scientific Secretary: **M. Gustafsson** (IAEA)

Round Table Presentation

A.C. McEwan
Christchurch, New Zealand

A comparison of hazards is based on an attempt to quantify risks. In the case of exposure to radiation, dose is used as a surrogate for risk, with risks based on an extrapolation of stochastic effects observed at doses well above occupational limits. In comparing risks of fatalities, it is worth keeping in mind that the risk expression arising from uniform exposure to radiation throughout a working lifetime peaks at late ages, and for the same fatality risk the years of life lost from exposure to radiation are much less than for prompt fatalities, for example, from industrial accidents.

In considering the topic, a first question is, how do we judge the adequacy of safety standards for avoidance of hazards? There are three widely used approaches. One of these, used commonly in the case of exposure to workplace chemicals, is to establish or estimate a threshold (e.g. for the concentration in air for continuous breathing) below which no harm is likely and accept exposures up to some fraction of the threshold as 'safe'. In the case of exposure to radiofrequency radiation, thresholds have been established for thermal effects and safety factors applied to these to derive occupational exposure limits.

A second approach is used in the case of some genotoxins and asbestos for which there may be no threshold, and it is then necessary to establish an exposure–effect relationship and reduce exposures to a level where risks are acceptable or at least tolerable. The question then becomes, what is a tolerable risk?

The third approach to standards setting is directed more particularly at avoidance of accidents which may result in 'grievous bodily harm' (e.g. a containment failure for liquefied chlorine). In principle, such events can be avoided by adopting appropriate engineering and administrative systems, and the probability of occurrence can be assessed through fault tree or probabilistic safety analysis. This allows some estimate of the risk of such an event to be made, although not necessarily an accurate estimate of the risk of health consequences. 'Safety' is judged acceptable if the risk is below some value which is considered attainable and acceptable for the industry.

There are obvious parallels in radiation protection. Exposure levels and dose limits are set below thresholds for deterministic effects and based on what is deemed to be an acceptable risk for stochastic effects, on the precautionary assumption of a linear no-threshold dose–effect response. Additionally, to minimize potential risk, facilities and sources are designed according to defence in depth principles, and generally, as in controlled areas, with rules or administrative procedures to minimize both routine exposures and the risk of potential exposures.

Over the more than 70 years that the International Commission on Radiological Protection has been in existence, the dose limits for occupational exposure have been revised several times, to take account of the changing types of radiation in use and to reflect more adequately both changed views of the tolerability of risk and revised estimates of the risk of stochastic effects. A test of the efficacy of current limits is to ask what impacts exposures to workers have had on health. Apart from the very high doses received by workers in the earlier years at the Mayak plant in the southern Urals, worker studies have generally failed to demonstrate any unequivocal health detriments, and in some studies, notably the British radiologists [1] and the nuclear shipyard worker study [2], superior health outcomes compared with controls were observed. In view of the fact that worker exposures have generally declined with time it would seem increasingly unlikely that studies of new groups would provide sufficient collective doses for any potential effects to be observable. However, further follow-up of already studied groups may help refine the statistical uncertainties.

Radiation standards, however, are much more than dose limits and the ‘as low as reasonably achievable’ principle, or application of the principles of limitation and optimization. They embrace all those activities overseen by radiation use facilities and operational health physicists of assignment of responsibilities, classification of areas, local rules, monitoring and dose assessment, training, quality assurance and audits. They also, as in the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [3], require the establishment and effective functioning of a radiation protection infrastructure in each country, one that includes a legislative base, the functioning of a regulatory authority carrying out authorization (by registration or licensing) of the use of sources, and inspection and enforcement. The infrastructure also requires nationally co-ordinated emergency plans, and the availability of supporting services for personal monitoring, instrument calibration and training.

So have the standards for radiation protection gone far enough? In view of the fact that it is doubtful whether current occupational doses in regulated practices are likely to give rise to any demonstrable stochastic effects, it could be considered that they have. Perhaps in some areas such as individual worker monitoring, and in the pursuit of controls on some naturally occurring exposures, they have gone too far. For example, in some countries the proportion of individual monitoring devices recording more than the minimum reporting level is less than 25% [4], and the fraction of workers exceeding 1 mSv/a is less than 3% [5].

However, the more important issue is the effective implementation of the standards. Comments on an e-mail discussion group earlier this year considered the best way to avoid accidents with industrial radiography sources. This followed the occurrence of a further significant overexposure in the United States of America. Much of the discussion centred on the necessity for ‘chirper’ ratemeters to provide an audible warning of radiation fields and their intensity. One contributor gave his opinion that "the best-spent money is for dependable, conscientious workers….. Good equipment enhances the worker, but the best equipment in the world will not stop all incidents when the users are inattentive or poorly trained."

Another contributor countered with a list of points:

(a) Continuous training and re-qualification is essential.
(b) Appropriate procedures are required and need to be reviewed and updated periodically.
(c) Management oversight is critical. Periodic management reviews are required to assess the programme.
(d) Appropriate equipment for the job must be provided.
(e) Staff members need to be familiar with all equipment, limitations and maintenance requirements.

It might be observed that all the above points are included in current standards such as the BSS [3] and the IAEA Safety Guide RS-G-1.1 [6].

Perhaps then, we can take the position that the standards have gone far enough, but that they need to be implemented and observed, most particularly with a view to avoiding accidents.

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Round Table Presentation

RADIOLOGICAL AND NON-RADIOLOGICAL RISKS: THE SEARCH FOR A GLOBAL APPROACH

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SCK•CEN,
Mol, Belgium

If everyone will agree with the statement that much effort has been made in the nuclear sector to minimize the radiological risks, there still remains work to be done if the aim is to reach the same level of protection as far as the non-radiological risks are concerned. The questions we want to address here are “Does a general approach for both kinds of risk exist and, if yes, how can we implement it?”

The reasons why such questions arise and the possible ways of solving them are examples of the points that will be treated here. One of our most important conclusions should lead to a necessary generalization of the optimization principle and to the need for paying more attention to the justification principle.

1. THE NEED FOR A GLOBAL APPROACH

Looking at some regulations from around the world, we can easily observe that the global approach to safety in the workplace has already been recommended for many years. Nevertheless, very recently, some regulators felt the need for not putting emphasis on this. Laws have been published, dealing more and more with the concept of ‘welfare’ in the workplace [1, 2]. In other words, people in charge of the protection of the workers were pushed into adopting a more multidisciplinary approach to the work and its consequences, not only in terms of safety but also as far as the ‘quality’ of the lives of the workers in the workplaces is concerned.

The nuclear sector has also been involved in such evolution. As a matter of fact, since the ‘birth’ of the ‘as low as reasonably achievable’ (ALARA) principle, more attention has been paid to other factors than to either the individual dose or the collective dose. Economic and social factors need to be taken into account. This is not the place for discussing the results of the optimization principle, but there is now enough evidence to show that the application of the ALARA approach has significantly increased the level of protection against the radiological risks.

Quite recently, the question dealing with a global approach has been addressed by almost fifty participants to the 4th European ALARA Network Workshop [3–4]. The conclusions will be dealt with later in this paper.

As another reason to justify the question mentioned above, it should be noted that in some circumstances the health physics and safety manager in nuclear installations is faced with situations where it becomes difficult to apply, on a straightforward basis, the principle of optimization. For instance, when workers have to remove asbestos from controlled areas, some choices have to be made and the question already mentioned may no longer be academic!

Furthermore, the trend towards ascribing more importance to the nuclear risks than to the 'conventional' one's is widely observed in the nuclear sector [5]. This may result, for example, in a transfer from radiological to non-radiological risk, sometimes with severe consequences for the victim!

With regard to the regulations, and taking advantage of what happens in the workplaces and considering the language which has to be used in such 'mixed' fields, it may be concluded that the search for a global approach to radiological and non-radiological risks is fully justified.

2. WHAT MIGHT A GLOBAL APPROACH LOOK LIKE?

Of course, this very short paper doesn't intend to try to provide the answer (if any exists!) to this question. The object here is to indicate some conditions which have to be fulfilled in order to reach a level of protection which some people refer to as 'ASARA', i.e. as safe as reasonably achievable. These conditions are based on the author's own experience with works where the question really arose for all the partners[1] and also on the conclusions which were drawn during the 4th European ALARA Network Workshop.

As a first statement, it must be recognized that the optimization principle may serve as a general guideline for achieving the global approach. As already reported [6], the very successful implementation of an ALARA procedure at SCK•CEN was due to significant reductions being achieved not only in the individual and collective doses but also in the frequency rates of conventional accidents.

However, the ALARA principle needs to be generalized. In the radiological field, indeed, it seems quite easy to work with the concept of dose that is quantitatively expressed and the factors that can have an influence on the level of the dose are well known.

The case of the non-radiological risks is not so straightforward; in this field only the frequency and severity rates can be used. However, these two quantities are a posteriori quantities! How can we optimize in such cases? How can we be sure that

[1] As regards Class I nuclear installations, Belgian regulations require that the head of the health physics and safety department assume responsibility for all kinds of risks.

the radiological optimization doesn't lead to a transfer between radiological and non-radiological risks? In other words, how can we be sure that we have optimized the total working conditions of the workers, without only focusing our attention on the radiological risks?

Some proposals for answering these questions may be summarized as follows:

(a) The 'design phase' of the works needs more effort from all the partners. A 'kick-off' meeting has to be planned; this will give the opportunity to participants to familiarize themselves with the working conditions and the limiting values for both kinds of risks and, last but not least, to set a common language. Depending upon the circumstances, representatives of the regulatory body should also be invited.

(b) The ALARA principle has to be implemented but may not be considered either as a 'computational' means or as the final goal; the ALARA principle is a powerful means of implementing a higher level of safety culture.

(c) Attention will also need to be paid to the knowledge of the workers themselves. As far as the workers are concerned, the general approach is very often limited to the 'top–down' communication. This kind of management is certainly not the best way to promote the safety culture needed to detect unsafe work conditions or to encourage the reporting of such conditions. Furthermore, there are examples enough where both partners have learnt much about each other owing to the attention given to their own point of view.

During the 4th European ALARA Network Workshop, the opportunity was given to almost thirty speakers to present their views and discuss their experiences concerning the management of radiological and non-radiological risks. Representatives of regulatory bodies, stakeholders, safety managers and trade unions provided very relevant contributions.

On the basis of the oral sessions and the discussions held during the working groups session, the following conclusions were made:

> "To effectively manage occupational risk(s) requires the development of a common risk culture among all stakeholders. It is therefore recommended that encouragement be given to including lessons and discussions concerning risk management in the day to day life during studies as early as at the school level. It is also recommended that strategies be set up at national and corporate levels to present and discuss occupational risk management with the workers, managers, media and public, as well as those in charge of regulations. It is also recommended that consideration be given to making regulations concerning risk management more clear and transparent, both in respect of the requirements and the culture needed to implement them;
>
> . . . .

> Risk transfer is a major topic we have, and will have more and more to deal with, not only between occupational risk but also between public and occupational risk and even between human and ecological risks. Therefore, it is mandatory to learn how to manage them, through a better knowledge of details of the actual transfers of risks, the factors involved and the interactions of the stakeholders in the decision making process. This could be achieved by developing studies to improve that knowledge, as well as research to define procedures and criteria relevant to making reasonable decisions;
>
> . . . .
>
> The participation of all concerned stakeholders appears to be a key element in arriving at decisions that are reasonable and receive broad acceptance."

3. PROVISIONAL CONCLUSIONS

This paper was not intended to provide an exhaustive review of the question concerning the management of both radiological and non-radiological risks. Owing to the complexity of the subject, the main wish of the author was to be provocative enough to launch discussion around this problem.

Indeed, the health physics and safety managers need to bear in mind that the allocation of money, time, etc., in the nuclear sector has to be optimized in the sense that the workplaces (and the risks attached to the works being performed) have to be considered as a whole, without paying more attention to one kind of risk than another. Safety of the workers cannot be divided into different fields. The uncertainties regarding the effects of the low doses are not, in the author's view, a sufficient reason to 'forget' the sources of many incidents/accidents with sometimes severe consequences for the victims.

More generally, the search for a global approach to the risks has to considered as a compulsory step in order to implement a common language as far as communication between all the nuclear partners, and with the stakeholders and the public is concerned.

It is to be hoped that this Conference will provide a good opportunity for exchanges between participants on this item and that this paper will be considered as a possible contribution for launching such contacts.

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Round Table Presentation

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The principal international standards in the field of occupational exposure are the International Commission on Radiological Protection–IAEA dose limit regime and the associated emphasis on the 'as low as reasonably achievable' (ALARA) concept. Their application over the last two decades has resulted in very significant exposure reductions from anthropogenic (human-made) radiation, both in collective dose and (particularly) in the number of workers exposed at higher exposure levels, say, above 15 mSv/a. This trend has been particularly evident in the nuclear industry.

Occupational exposure to natural radiation (naturally occurring radioactive material/technologically enhanced naturally occurring radioactive material) has not in general followed the same pattern, with only limited achievements in dose reduction. The majority of the highest levels of occupational exposure are now the result of natural radiation, measured either as contributions to occupational collective dose or as the number of workers exposed above 15 mSv/a. Despite these relatively high contributions to societal risk, there is evidence that natural radiation exposures result in less societal concern than do other types of radiation exposure, where sociological research indicates that a particularly high 'dread factor' influences the perception of radiation risk.

The risks from radiation are generally well understood and are quantitatively well bounded, although there is of course some continuing debate, particularly that concerning the linear no threshold hypothesis. Few other risks in modern society are as well bounded, and very few indeed are as amenable to quantification and control at the individual worker level.

The current framework of dose limits and ALARA has resulted in occupational exposure patterns and resultant risks which appear to be broadly compatible with risk levels generally acceptable in society and which are broadly comparable with the range of non-occupational natural background radiation exposures. There is therefore very little to be gained from any further tightening of this framework, and indeed there are likely to be several parts of the world where general occupational and wider societal risks are significantly higher than those resulting from radiation exposure under the current regime. In such circumstances it could be argued that a less stringent application of radiation protection standards could allow a more equitable and cost effective approach to total risk reduction.

The application of the ALARA principle is, and should remain, the key controlling influence for occupational exposure. Its application is multifaceted, and the following components should be considered:

(a) Engineering options, e.g. shielding, ventilation, robotics and workplace re-engineering. Such applications will usually incur financial costs.
(b) Management systems: the approach to radiation control should always be integrated within the wider management system. The application of appropriate quality procedures, including assessment and review, should result in a radiation protection programme which can deliver appropriately low doses through efficiency and effectiveness savings.
(c) Safety (ALARA) culture: through training, awareness and involvement the workforce can be motivated to play a vital and effective role in dose reduction.

In these latter two components there will usually only be marginal cost/resource implications relating to specific ALARA aspects, and in many cases these may be offset by operational benefits (so-called ‘win–win’ optimization).

A very strong emphasis must be given to all aspects of ALARA where exposure levels are at a significant fraction of the dose limit. The main ALARA programmes should be focused around these higher levels of individual exposure. At low levels of occupational exposure, say at around 2 mSv/a or less, further exposure reductions will not make any significant change to the total risk level experienced by an individual (e.g. including natural background radiation exposures and other contributions to occupational risk). Hence, it would be inappropriate to divert society’s resources to seek exposure reductions at this level. Noting the above analysis of ALARA contributions, it can therefore be argued that in such circumstances little (if any) attention should be given to engineering contributions (except possibly where effective exposure reductions can be introduced at the design stage). However, a continued and balanced inclusion of radiological and ALARA considerations in management system and safety culture programmes is necessary.

So against this background, how low can (or should) occupational exposures go? There are many different factors which act to differing extents on the various sectors, and hence it is very unlikely there will be a uniform level of ambition. These factors range through regulatory pressure, management–worker relationships, peer group pressure, public perception and acceptability, moral/ethical issues, the practicability of dose reduction measures, and the ability to provide finance and resources. As a simple example, it may be the case that the nuclear industry has been prepared to put higher levels of resource into reducing doses than has been the case in the health service or into reducing occupational exposure to radon because of significant differences in public perception and image, together with a less cost conscious environment. However, this balance could change as electricity generation becomes more cost sensitive and the cost challenges of addressing defence liabilities become more prominent.

One framework within which this issue could develop involves focusing the debate on low levels of occupational exposure and restricting it to management and its workforce, taking account of the mutual ambition for continued safe employment together with sector perception issues. The regulatory authorities have little or no contribution to make or role to play in this situation. At higher levels of exposure, the national policy makers and regulators have an increasing interest and involvement in providing a guiding framework to prioritize the ALARA focus.

Finally, it should be noted that the above considerations apply to routine ‘expected’ occupational exposure. However, even in situations where normal exposures are expected to be low it is necessary to ensure that the risks of accidental/abnormal exposure are assessed and suitably minimized.

Round Table Presentation

G.P. de Beer
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Pretoria, South Africa

I think at this late stage it's really difficult to present something new because the subject has already been discussed fairly widely in previous presentations. What I want to do is just to emphasize some of the points that have already been discussed, specifically from the perspective of the developing countries, namely, that the present standards and the social risk system are mainly based on the socioeconomic conditions prevailing in developed countries and that developing countries generally have different socioeconomic conditions sometimes requiring adaptation. The way this manifests itself is that in the developing countries we normally have higher societal risks and eventually the situation develops where there is a rather large imbalance between the risks normally accepted for workers and those in the society. I can just give a few examples; namely, that the mean life expectancy is not only a function of the risk people are exposed to but is also some function of the annual gross national product (GNP) in the country, and at the higher levels we note that the dependencies are very low, which means that for the higher GNP figures of the day, this reduction may be the preferred option to take to increase life expectancy. However, at the lower end of the spectrum the life expectancy is to a large extent dependent on the GNP in the country and in the developing countries this is very important. Therefore, one way to actually increase the life expectancy of people is to create the jobs to increase their productivity which will move them into the situation where they can afford medical attention, proper housing, etc.

A particular problem at the moment in the developing countries is the presence of HIV-AIDS, and while it is a societal risk it also has some impact on the occupational risk because it breaks down the human immune system and as such also increases susceptibility to occupational risk. The severity of this impact on standards and how to deal with this need further investigation. Thus, the conclusion drawn is that the present standards have gone far enough, but the question is whether they have been broad enough and I think in this respect we really need broader guidance on the way to handle the interface of societal risk in the developing countries.

ROUND TABLE 2

DISCUSSION

A.C. McEWAN: One of the questions that has been raised relates to differences between developing and developed countries and to the amount of money that should be spent on radiation protection in a given country if, say, the HIV infection rate is 40%.

A.J. GONZÁLEZ: In my view, the context of this Round Table concerns the question of whether our present radiation protection standards are too ambitious or not ambitious enough.

The data presented by J. Lochard showed clearly that there is very little justification for complacency. Consequently, I was surprised when, in his oral presentation, R. Coates accused the ICRP and the IAEA of being "presumptuous" in striving for a universal level of ambition. He appeared to be suggesting that, say, a very high crime rate in a given country could justify complacency about radiation protection standards in that country. In my opinion, that would be a very dangerous road to follow.

The issue is not one of developing vis-à-vis developed countries. Should the radiation protection standards in hospitals in those parts of London where the crime rate is very high, perhaps higher than in many developing countries, be different from the radiation protection standards in hospitals in other parts of London?

I would recall in this connection that about 20 years ago the ICRP put forward the argument that, when you have two situations, if you optimize one of them and then the other, the result will be an optimized one. I see no reason why one should not seek to optimize in the area of crime prevention and in the area of radiation protection simultaneously. What one should not do is to say "the standards in the radiation protection area ought to be relaxed because of problems in the area of crime prevention."

R. COATES: My main point was that, in my view, the standards are about right; they do not need to be made more rigorous, and that, given this situation, we should perhaps be focusing on how to derive the greatest benefit from the resources available for health and safety improvement.

R.T. LOUW: In my country, the average life expectancy at birth is about 48 years and there is an unemployment rate of about 35%. If we accept that high unemployment means a great deal of poverty and that a great deal of poverty means a low average life expectancy, should the South African mining industry create new jobs involving individual exposures of, say, 50 mSv/a?

G.G. EIGENWILLIG: That is an argument for reducing health and safety standards in order to reduce unemployment, and I cannot go along with it. In the eastern part of Germany, for many years after the Second World War, rather similar arguments were put forward in order to avoid hampering the mining of uranium ores; the health and safety standards in existence were simply not applied.

Once again I would recall the objectionable sentence in paper IAEA-CN-91/92 about the risk of being murdered in South Africa. Does one reduce the standards of worker protection in a country because, say, a civil war has broken out there? I agree with A.J. González in this matter.

A.C. McEWAN: We have heard two valid, but conflicting, points of view, one focusing on the raising or maintenance of radiation protection standards and the other on the extraction of maximum benefit from the resources available for health and safety generally.

J. VALENTIN: I find it hard to imagine that in a developing country, with low labour costs, it is prohibitively expensive to keep occupational radiation doses in the mining industry below 50 mSv in one year and 20 mSv/a over a series of five years. In my view, if the mining industry in a developing country cannot achieve that, it is not organized in a sensible manner. Moreover, I doubt whether mining companies create jobs in order to reduce unemployment. They do so in order to increase their profits.

A.J. GONZÁLEZ: Further to what J. Valentin just said, I would recall that, when the International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) were being developed, mining industry representatives argued that a dose limit decrease from 50 mSv/a to 20 mSv/a would force many mines to close, with catastrophic results in terms of greater unemployment.

In fact, no mines closed as a result of a decrease. All that was necessary were improvements in mine ventilation and in occupational radiation protection practices.

As J. Lochard showed in Topical Session 1, the levels of ambition have been rising in most areas relevant for the health and safety of workers. The level of ambition in the area of occupational radiation protection should not be an exception. As I said earlier, there is very little justification for complacency. It is no longer true that the situation in the occupational radiation protection area is much better than the situation in the other areas; there is not much difference anymore.

J. LINIECKI: I believe that a relaxation of occupational radiation protection standards would have catastrophic consequences.

However, in a country with a per capita GNP of, say, $1000, is it reasonable to demand that vast amounts of money be spent on reducing occupational radiation exposures? A highly developed country may be willing to spend, say, $50 000 per man·sievert averted, but one cannot expect that of a developing country.

In my view, that was what R.T. Louw was driving at. He was advocating a reasonable allocation of the available resources, not a relaxation of occupational radiation protection standards. Optimization is the best tool, but it should be used in a flexible manner.

S. VAN DER WOUDE: As a regulator, I believe that it would be dangerous to relax occupational radiation protection standards and that a universally accepted set of standards is the best solution.

I agree with J. Liniecki, however, that the tool of optimization should be used in a flexible manner. Therefore, I believe that developing countries need international guidance on how to apply the ALARA principle.

A.J. González was right in saying that no mines closed as a result of the lower dose limits in the BSS. In South Africa, thanks, inter alia, to close co-operation among stakeholders, doses were reduced, and South African mining companies have in recent years been among the few companies making profits.

F.J. MORALES: In Nicaragua, there is very little money available for occupational radiation protection, but we nevertheless base ourselves on the internationally accepted occupational radiation protection standards. What other standards should we apply?

When a radiation practice is introduced, all the associated costs — including the costs of occupational radiation protection — must be met. It is a matter of ethics; our radiation workers are not second class human beings.

G.A.M. WEBB: In my view, although the standards of occupational radiation protection, and especially the dose limits, should remain the same for all countries, the optimization of occupational radiation protection is a case specific exercise. The standards do not require the same level of ambition everywhere regardless of local circumstances.

Also, we should not forget that, as R. Coates said, optimization is nowadays to a large extent "win–win optimization"; you do not have to spend a lot of money, you simply have to create the right organizational structure and ensure that everyone is reasonably well trained and thinking in the right way. That can be done in developing countries just as effectively as in developed countries.

Another point I should like to make is that, as advocated in the Round Table 1 discussion, occupational radiation protection should be treated as a part of the general effort to improve worker health and safety. If that is accepted, the IAEA and the ILO should perhaps work more closely together in ensuring that occupational radiation protection is integrated more fully into general worker protection.

F.I.M. NOLAN: In the light of our experience in Canada, especially in the uranium mining industry, the institution for which I work, which is not a governmental body, would undoubtedly support the retention of universally accepted occupational radiation protection standards.

In Canada, we have had an occupational radiation protection disaster followed by a remarkable success. Some 200 miners have died of lung cancer due to exposure to radon progeny in the old uranium mines in Ontario, where we did not succeed in getting the international standards applied.

In the new uranium mines, in Saskatchewan, where the international standards are being applied and improved radiation protection technologies implemented, the radiation exposures are really being minimized. This is partly due to the involvement of the public, which did not accept the argument that the mining industry would suffer if more rigorous occupational radiation protection standards were applied.

J. LOCHARD: In applying the ALARA principle, I focus on the most exposed workers, trying to reduce their exposures in such a way that the viability of the facilities where they are working is not endangered.

While I have the floor, I should like to ask R. Coates what he thinks the level of ambition should be for the dismantling of nuclear facilities over the next 30–50 years.

R. COATES: We have a regime with a dose limit of 15 mSv, and we try to keep as many people as possible below 10 mSv. I believe that future decommissioning operations can be accommodated by that regime.

Incidentally, I thought that the comment in my presentation which would provoke most discussion was the one to the effect that, with the very low dose levels now prevailing, the issue of occupational radiation protection should be dealt with bilaterally by the employers and the employees, without the involvement of regulators.

D.J. BENINSON: In this discussion there have been references to ‘optimization’. I should like to point out that optimization in occupational radiation protection is the interplay of, on the one hand, protective measures and, on the other, the associated social costs. The issue of the allocation of the resources in developing countries available for health and safety measures has nothing to do with optimization in occupational radiation protection.

E. AMARAL: In Brazil, the doses to the workers in medicine, in industry, at nuclear power plants and in uranium mining are far below the limits set by the international standards. The only problem that we regulators have is with coal mining, where we have measured workers’ doses of 10–20 mSv/a. We have difficulty in persuading mine owners to reduce the worker exposures even though reducing them is not very difficult. Exposures can be reduced significantly simply through the introduction of improved ventilation and basic hygiene procedures; if the coal miners all washed their hands before eating at the mines, protection against radiation exposure and other health hazards would be enhanced.

T. TANIGUCHI: We in the IAEA Secretariat are trying to strengthen the international nuclear and radiation safety standards in order to improve safety and thereby increase public confidence in nuclear and radiation technologies. The application of different standards in different countries, depending on each country’s stage of economic development, would run counter to our approach.

Some time ago, in the Intergovernmental Panel on Climate Change, of which I am a former vice-chairperson, the idea was put forward of assigning different monetary values to the lives of people as a function of the stage of economic development of the countries where they were living. That idea, which was severely criticized and ultimately dropped, is rather similar to the idea of applying different nuclear and radiation safety standards in different countries in the light of each country's stage of economic development. The credibility of the nuclear energy community, which is already viewed with a great deal of suspicion, would suffer enormously if this idea were strongly pressed. This matter is one of great concern to me as the IAEA's Deputy Director General for Nuclear Safety.

A.C. McEWAN: I think T. Taniguchi's point about the credibility of the nuclear energy community is a very important one.

D.C.D. URQUHART: With regard to R. Coates's comment about the exclusion of regulators when dose levels are very low, the bilateral ALARP (as low as reasonably practicable) approach has been adopted to some extent in the UK.

We, the regulators, have a 'basic safety limit' which we do not like to see exceeded and a 'basic safety objective' below which we cannot justify regulatory effort given the scarcity of our resources. It is perhaps no coincidence that the 'basic safety objective' is 2 mSv.

Although often not participating in ALARP exercises, we would hate to think that, just because the doses are very low, the employers are no longer vigilant. We and the employers still have responsibilities.

S. NIU: The fact that, thanks to successful efforts in the area of occupational radiation protection, radiation hazards in the workplace are now insignificant compared with other workplace hazards does not mean that we can become less vigilant. There is still room for improvement in the area of occupational radiation protection, although resources should not be expended on minor problems, and the lessons learned in that area can be of value in areas where the threats to worker health and safety are greater.

With regard to the discussion about whether the approach in developing countries may be different from that in developed countries, for me the important issue is the approach at the enterprise level.

ROUND TABLE 3

CAN CONTROL OF OCCUPATIONAL EXPOSURE TO NATURAL RADIATION BE MADE COMPATIBLE WITH CONTROL OF OCCUPATIONAL EXPOSURE TO ARTIFICIAL RADIATION?

Chairperson: **G.C. Mason** (Australia)

Round Table Members: **J. Piechowski** (France)
L. Tommasino (Italy)
J. van der Steen (Netherlands)
M.A. Waters (United States of America)

Scientific Secretary: **M. Gustafsson** (IAEA)

Round Table Presentation

A SPECIFIC CASE: COSMIC RADIATION EXPOSURES OF FLIGHT CREW

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The average annual effective dose due to occupational cosmic radiation exposure is 3.0 mSv (about 60% neutrons), which is higher than that due to other enhanced natural sources such as coal mining, non-coal mining or mineral processing according to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) 2000 Report. Individual variability in annual exposures can be up to 25 fold (0.2–5 mSv/a), depending on the routes flown, which are often related to seniority in the profession. The collective dose for aircrew is 320 man·Sv/a (UNSCEAR 1993 Report).

In the specific case of cosmic radiation exposure of aircrew, the radiation control options include rotation of staff for reduction in individual hours worked, reduction in aircraft altitudes, reduction in flight route latitudes and postponement or rerouting of flights during known solar particle events. In the classic occupational hygiene exposure control paradigm, these measures would be categorized as administrative controls: reducing the time exposed or increasing the distance to source. Clearly, there are no feasible engineering controls or personal protective controls such as aircraft or personal shielding.

International Commission on Radiological Protection Publication 60 (1991) provided international recommendations that practices involving radiation exposures be justified by benefit to individuals or society, that protection be optimized by constraining individual doses or risks, and that limits be set for individual doses and risks. Additionally, proposed interventions should do more harm than good and the cost–benefit should be maximized. However, from a regulatory standpoint, differences exist between countries in the approach taken.

In the United States of America, aircrew are not yet considered ‘radiation workers’ and occupational exposures to cosmic radiation are still treated as unregulated natural background radiation. The US Federal Aviation Administration (FAA) provides educational materials to increase awareness among flight crew, supports research and provides a tool (computer model) for estimating doses received on individual flights so that individuals or companies may assess total doses. Additionally, the US FAA has recommended that commercial airline companies provide education and training to aircrew, which some companies already do.

Within the European Union, the Council Directive 96/29 Euratom (Articles 10 and 42) specifies that each Member State shall make arrangements for undertakings operating aircraft to take account of exposure to more than 1 mSv/a. The undertakings shall take appropriate measures, in particular:

(a) To assess the exposure of the crew concerned,
(b) To take into account the assessed exposure when organizing working schedules with a view to reducing the doses of highly exposed aircrew,
(c) To inform the workers concerned of the health risks their work involves,
(d) To ensure that the dose received by the foetus is kept as low as reasonably achievable and be unlikely to exceed 1 mSv following declaration of pregnancy.

Both artificial radiation and naturally occurring occupational radiation exposures and risks require regulatory control, although the mechanisms for routine monitoring to achieve compliance will differ. For aircrew exposures to cosmic radiation, dose estimation rather than measurement is sufficient in most cases owing to the availability of reasonable, accurate models. Although exposure data are available and guidance has been developed for controlling aircrew exposures, there has been slow acceptance of this guidance outside Europe. There will be economic barriers to implementing some methods of exposure control, such as reducing flight altitude or re-routing, which incur fuel cost penalties, or flight postponement during significant solar particle events. In some cases, there may be resistance from affected flight crew, since seniority permits selection of schedules and higher dose schedules are more desirable since they involve fewer trips per month. As with reduction of artificial radiation exposures to as low as possible, optimization of protection against cosmic radiation exposures will require a balancing of societal, industrial and individual good.

Round Table Presentation

L. Tommasino
Agenzia Nazionale per la Protezione dell'Ambiente,
Rome, Italy

When dealing with natural radiation sources, a flexible regulatory approach is needed to take into account national circumstances, which may require country specific approaches for the identification of those exposures considered as being occupational. Attempts will be made here to point out those differences which could be important when dealing with natural and artificial radiations, while at the same time stressing the importance of avoiding different standards whenever possible, as in the control of occupational exposures.

The most interesting natural source of radiation is radon, owing to its widespread occurrence and capability to form high concentrations. In particular, guidelines for the solution of the radon problem in workplaces may be derived from the exposure data accumulated to date on two extremely different cases: uranium mines and dwellings.

It appears clear to everyone that exposure to radon in uranium mining needs to be treated as a practice and subject to the occupational dose limit. On the other hand, it is just as clear to most people that exposure to radon at home is an intervention situation [1]. Between these two extremes there exist all possible situations involving exposure to radon in workplaces, which may range from ordinary places of work such as offices to non-uranium mines. The major problem is to identify whether the exposure to radon at work is due to natural background or whether it should be classed as occupational exposure.

The approach recommended by the International Commission on Radiological Protection [2] is that the philosophy of intervention in homes be carried across to the workplace to provide a rationale as to when radon exposure at work is to be classified as occupational. When a workplace is identified as having a radon gas concentration above the action level, the first option taken is to adopt remedial measures which lower the radon level. In such circumstances, the radon exposure should not be treated as occupational exposure if it is below the action level. Only if exposures are above the action level should they be treated as occupational exposures and become subject to the dose limits, requirements for individual monitoring and dose record keeping [1].

In brief, once identified, the workplace is to be subject to control of the occupational exposure: employers must comply with similar requirements to those applied to practices involving artificial radionuclides.

The International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) [3] adopt the same recommendations as those of the ICRP [4] and thus classify the exposures to natural radiation either as an intervention situation or as a practice.

In addition to the two above categories, the European Basic Safety Standards Directive [5] introduces a third category — work activities involving exposure to natural radiation sources. In a simplified classification proposed by Daroussin and Brillanceau [6], when the exposures due to natural radiation are the consequences of work activity (e.g. aircrew exposed to cosmic rays), it would be quite logical to deal with such exposures as practices. On the contrary, when such exposures are independent of work activities (e.g. radon in office buildings), they are more likely to be dealt with as intervention situations.

The European Directive deals with natural sources within the same general framework as other exposures to radiation. This approach facilitates comparison of the procedures to be followed for natural and artificial radiation sources respectively and identifies differences and similarities among these procedures. While the ICRP [2] provides quantitative recommendations (which have been endorsed by the BSS) only for radon, the European Directive, in addition to the radon action level, proposes an annual effective dose of 1 mSv for aircrew exposure as a reference level above which the system of radiological protection is applied.

Even though this dose value applies to the specific case of aircrew exposure, it constitutes a landmark for other work activities [6]. As a result of this precedent, the guidance provided in Article 31 Experts [7–9], with regard to the implementation of the Directive has recommended an annual effective dose of 1 mSv as a reference level for other exposures to natural radiation, such as NORM, etc. This dose value has been implemented in many European countries [6]. Achievement of harmonization is strongly required and should be especially recommended to those countries outside the European Union because what are being dealt with are such international activities as aircraft operations and the economic implications of controls imposed on worldwide industries processing raw materials. To this end, it is important that the same reference levels be endorsed by IAEA Member States.

Another important difference between natural and artificial sources is that the release from regulatory control of artificial sources is meant to result in nothing but negligible exposures (a dose criterion of 10 μSv per practice), whereas in the case of natural radioactivity a negligible exposure is not quite meaningful [10] since a level of radioactivity should correspond to acceptable levels of exposure (e.g. a dose criterion for exemption of 300 μSv for work activities) below which there is little scope to achieve a reduction in exposure through regulatory control [10].

Differences in radiological protection with regard to natural and artificial radiations exist and are justified prior to the identification of occupational exposures due to natural radiation as practices. If not a practice, the exposure to natural radiation is only natural background and constitutes only a disturbing factor when assessing the occupational exposure to artificial radiation. However, once the work activities are identified as practices, they should become subject to rules equivalent to practices applied for artificial radiation (i.e. declaration, measurement, reporting); all the elements necessary to ensure good health protection of individuals. To this end, the same standard should be applied to the control of occupational exposures due to artificial and natural radiations respectively.

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Round Table Presentation

J. Piechowski
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The radiation protection programme for non-nuclear industry involving natural radionuclides cannot be similar to that which is applicable to the nuclear industry or to medicine. However, the general objectives are the same: reduction of exposure to ionizing radiation and compliance with the dose limits.

In the case of natural radioactivity, exposure is chronic and relatively stable or slowly increasing with time owing, for instance, to the progressive accumulation and concentration of radionuclides in certain residues.

Accidents involving acute irradiation are virtually impossible with the natural radionuclides in the mines and ore processes (use of sealed sources for some specific tasks, such as gammagraphy, is not considered here), so that a special monitoring programme is not actually needed, although some particular measurements may be useful in identifying or confirming limited areas of high natural radiation, but this has nothing to do with prevention of accidental acute exposures.

Routine monitoring involving extensive use of ambient monitoring is essential. Exposure of workers is mainly related to chronic external irradiation, at a relatively constant level, and to chronic internal contamination with a slowly increasing body burden due to inhalation of long lived radionuclides. These radionuclides are not easy to measure, especially thorium. What is due to natural normal intake is sometimes difficult to distinguish from that due to occupational exposure.

A recurrent problem is inhalation of dust, but of more importance is the question of exposure to radon and thoron. Particular actions (ventilation) and specific dosimetry are generally needed. In most cases, ambient monitoring of radon at the workplace is sufficient.

Finally, specificity rather than compatibility is certainly more appropriate when considering the difference between exposure to natural and artificial radionuclides. Specific procedures and actions have to be developed for non-nuclear industry involving natural radionuclides. They should include appropriate optimized technical aspects of physical protection and relevant surveillance with emphasis on ambient monitoring of the critical workplaces.

The key issue concerns the introduction of the radiation protection culture to old industries that already have well-established technical processes and where occupational hygiene is frequently limited to conventional prevention of dust inhalation and traumas.

Round Table Presentation

J. van der Steen
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According to the United Nations Scientific Committee on the Effects of Atomic Radiation 2000 Report, occupational exposure due to natural radiation is estimated to account for more than 80% of the worldwide annual collective dose due to occupational exposure, uranium mining excluded. Several studies, carried out in the last 10–15 years, have also shown that the individual doses to workers exposed to naturally occurring radioactive materials (NORM) in industry can be significant. Another special feature of exposure to natural sources is that doses are in many cases due to internal exposure, either by inhalation of radon in workplaces or by inhalation of aerosols in dusty working conditions. When the employer is unaware of the problems associated with enhanced levels of NORM in raw materials, products or residues and when no protective actions are taken, the doses may even exceed the occupational dose limit.

Three main points are relevant with regard to managing and reducing the exposure to NORM, namely, awareness, regulations and guidance. Within the European Union (EU), the Council Directive 96/29/Euratom (Euratom Basic Safety Standards) paid specific attention to natural sources of radiation. EU Member States are obliged to identify the work activities that cannot be ignored from a radiological protection point of view and declare parts of the Directive applicable in their national regulations with respect to natural sources. This has increased the awareness enormously, and most of the Member States have now implemented regulations in their national legislation. Also, the 1996 International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources (BSS) address the control of exposure to natural sources. In the mean time, a number of international meetings were dedicated to the radiological consequences of NORM and these have played a role in leading to a worldwide acknowledgement of the issues involved. Nevertheless, the state of knowledge with respect to the radiation protection problems associated with NORM still lags that of artificial radionuclides.

As far as the general objectives of control of occupational exposure to ionizing radiation are concerned, one can conclude that owing to the above-mentioned developments, control of exposure to NORM leads to reduction of collective and individual occupational doses and, generally, to compliance with dose limits. Yet there remain some specific issues that make it difficult to reach compatibility with control of exposure to artificial radiation. These issues are partly related to the intrinsic differences in regulating artificial and natural radionuclides, and partly to the ‘arrears’ built up in a structured approach used to introduce radiological protection measures for optimization of internal exposures in NORM industries.

1. SCOPE OF REGULATORY CONTROL

The selection of appropriate criteria for defining the scope of regulatory control is a critical issue for NORM. The number of industries potentially subject to regulatory control is very large and although the radiological hazards can in some cases be very significant, inappropriate selection of criteria could result in many industries being regulated without any net benefit in terms of risk reduction. The exemption levels specified in terms of activity concentration and total activity in both the BSS and the Euratom Basic Safety Standards are based on an individual dose criterion of the order of 10 μSv/a and a collective dose criterion of about 1 man·Sv/a. Doses below these criteria are considered internationally as being of no regulatory concern, or trivial. These exemption criteria are applicable for practices with artificial radionuclides with moderate amounts of material, but are not applicable to bulk quantities of natural radionuclides. Although one can argue that persons exposed to NORM should be subject to the same radiological protection standards as those that apply to persons exposed to artificial radionuclides, the dose criteria of 10 μSv/a and 1 man·Sv/a are widely regarded as being impractical for NORM industries. The range of doses resulting from terrestrial radiation (excluding radon) lies between a few hundred microsieverts per year to a few millisieverts per year. The corresponding variation in activity concentration ranges from a few hundredths of a becquerel per gram to a few becquerels per gram. Applying dose criteria of 10 μSv/a and 1 man·Sv/a to NORM activities would bring large areas of the world under regulatory control. International Commission on Radiological Protection Publication 60 refers to a second basis for exemption, other than exemption on the basis of trivial dose, namely, that "no reasonable control procedures can achieve significant reduction in individual and collective doses." This basis for exemption is more appropriate for NORM activities than the trivial dose basis, but is not reflected explicitly in the BSS.

For the reasons mentioned above, the EU has published a guidance document (RP122 Part II) on the issue of exemption (and clearance) of natural radioactive sources, based on an individual dose criterion of 300 μSv/a. Despite the guidance, there is little harmonization in practice, specifically that dealing with the establishment of exemption and clearance levels for NORM. One can conclude that current international guidance on scope defining criteria for NORM regulation is inconsistent and incomplete.

2. REGULATORY REQUIREMENTS

For many NORM industries, simple control measures, similar to those already in place for normal occupational hygiene reasons, may often provide sufficient radiological protection. In many industries, occupational hygiene requirements are imposed as a matter of course by a regulatory authority that may not have particular knowledge of radiation hazards. Guidance is needed for both the operator and the regulator on appropriate control measures, and the extent to which these can be implemented by normal occupational hygiene requirements.

The 'grey' area between practice and intervention poses a particular problem for NORM because many industries already existed long before (radiological) regulatory control was established; the same is true of their bulk wastes which have been exposed to the environment. Regulatory control of these industries therefore has to be applied retrospectively. If they are treated as true practices, this may impose impractical requirements on many industries where radiological protection was not taken into account in the design of facilities. Non-uranium/non-thorium mines have in many cases been operating for several decades and are only now being brought under regulatory control. Many mines have managed to accommodate the retrospective introduction of radiological protection requirements. However, in some instances, achievable reductions in radon concentrations are not sufficient to ensure compliance with dose limits, owing to the physical difficulty and high capital cost of making major changes to the ventilation system. Rigid enforcement of dose limitation requirements would most likely result in the affected shafts having to close prematurely, with potentially severe implications for the workforce given the high unemployment situation in some of the regions where these mines are situated.

3. KNOWLEDGE AND AWARENESS OF HAZARDS AND EXPOSURES

As NORM industries traditionally have not been subject to radiological protection measures, there is a general lack of awareness and knowledge of radiological hazards and exposure levels among legislators, regulators and operators (particularly operators of small businesses). Despite the number of international meetings dedicated to the radiological consequences of NORM, the knowledge of the legislators and regulators with respect to the various minerals and their management, processing and use is still lagging. On the other hand, operators and downstream users of the materials lack knowledge of radiological protection and are often fearful of the implications of regulation.

4. RADIOLOGICAL PROTECTION MEASURES

Up to now, and in contrast with external exposures, relatively few efforts have been devoted directly to implementing the 'as low as reasonably achievable' approach for internal exposures. For practices involving artificial radionuclides, internal exposures are in most cases not the dominant exposure pathway. However, owing to the large volumes of NORM containing materials in industry, in connection with dusty work conditions, internal exposure is in many cases the dominant potential exposure pathway for NORM. Exposure situations of workers in these industries differ considerably with respect to type of industry, workplace conditions and radionuclides involved. There is a need for guidance on appropriate radiological protection measures for workplaces in NORM industries, specifically for recommended monitoring strategies and methods for optimization of internal exposures. This guidance needs to be specific for the type of industry and be directed at assisting regulatory bodies and operators identify effective ways of meeting the radiological requirements. Specific guidance is also needed on effective means for reducing radon concentrations in air and water, given that, without appropriate controls, radon concentrations can reach very high levels even where uranium and radium concentrations in the raw material may be very low.

5. CONCLUSIONS

While the issues related to the lag of knowledge of NORM problems can be solved in due time, the intrinsic differences in the scope of regulatory control of natural radionuclides in comparison to artificial sources will remain and will necessitate a different approach. When compatibility of control of occupational exposure is defined as reaching the optimum level of protection, below which no reasonable control procedures can achieve significant reduction in individual and collective doses, one may come to the conclusion that compatibility between the two types of exposure can be reached, albeit not at the same dose level. However, there is a substantial need for further international guidance, both for regulators and operators, before this is the case.

ROUND TABLE 3

DISCUSSION

T.C. CARDWELL: Yesterday, R.T. Louw, from South Africa, seemed to be calling for regulatory flexibility in view of economic problems in his country. Today, we have heard that, owing to the complications of regulation, in the case of NORM it is impossible to enforce the standards which are enforced in the case of human-made radioactive material.

Here, we are talking about occupational, not public, radiation exposure, however, and in my view we cannot have it both ways. The problem may be one of identifying those industries where there is NORM resulting in occupational exposure rather than one of really enforcing the standards.

G.A.M. WEBB: I feel uneasy about switching from a control regime for practices to one for interventions and then, if the results are unsatisfactory, switching back. It might be better to approach the control of occupational exposure to NORM in the same way as one approaches the control of other kinds of occupational exposure.

In my view, many regulatory decisions are applications of optimization of protection, which, of course, has to take account of economics, practicality, social aspects, etc.

No one would carry out an optimization study and then insist on imposing unreasonable standards; such insistence would mean that the optimization study was not a good one. The outcome of the optimization study, which would be industry by industry, might well be that regulation was not the best approach in the industries covered. There would then be a good radiation protection basis for the regulatory decisions.

In my view, what we are actually talking about here are regulatory decisions about whether or not to impose the requirements for practices; if you do not impose those requirements, you are not really doing anything.

Perhaps we should consider trying to take regulatory decisions in the light of broad optimization studies, on the understanding that we are trying to treat occupational radiation exposure in the same way irrespective of the cause. I think that suitable mechanisms could be found and that exemption levels and the like would be irrelevant.

G.C. MASON: G.A.M. Webb seems to be advocating a graded approach to regulation.

One of the concerns in some sectors of industry is that, once one is caught in the regulatory net, one will have to comply with all the requirements of the International Basic Safety Standards or with equivalent national requirements. We are beginning to realize that it is sensible to have a graded approach to regulation.

K. SCHNUER: Regarding G.A.M. Webb's comment about practices and interventions, I should like to mention that the EU's basic safety standards (Council Directive 96/29/Euratom laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation), which represented the first attempt to include the NORM issue within a regulatory framework, distinguished between practices and work activities.

The distinction is a purely legal one. It does not mean that a work activity is not regarded as a practice or that a practice is not regarded as a work activity. What it does mean is that for a work activity not all the principles underlying the EU's basic safety standards (justification, optimization, limitation and so on) apply. For example, the justification principle cannot apply in the operation of aircraft, the manufacture of fertilizers or the use of gypsum.

The EU's basic safety standards specified that, for example, ^{40}K and cosmic rays at sea level should not be considered and made special provision for natural radionuclides which are processed but not for their radioactive, fissile or fertile properties. When natural radionuclides are processed for their radioactive, fissile or fertile properties, the basic safety standards treat that as a practice.

The question of which industries have to meet further requirements was left open for the EU Member States to decide in the light of geographical, historical and other considerations.

During the past ten years, the European Commission has frequently been asked by EU Member States about radiation protection in particular industrial sectors. Recently, for example, it was asked about radiation protection in enterprises which recover and recycle fluorescent lights containing small amounts of krypton and promethium. That was a question not anticipated ten years ago.

With regard to the radiation protection of aircrews, the Joint Aviation Authorities, representing the national aviation authorities of the EU Member States, recently adopted new standards and operational procedures in response to Article 42 of the EU's basic safety standards, which is based on the application of the ALARA principle to highly exposed workers rather than on the observance of a dose limit. At the same time, Article 42 specifies special protection requirements for female aircrew members.

As to the question constituting the title of this Round Table, "Can control of occupational exposure to natural radiation be made compatible with controls of occupational exposure to artificial radiation?", I would say that it can be made compatible, but we still have a long way to go.

J. VAN DER STEEN: G.A.M. Webb implied that exemption levels were not the best basis for dealing with NORM and I agree with him. That is why, in my oral presentation, I said that in my view the second basis for exemption in ICRP Publication 60 is better for dealing with NORM.

The second basis for exemption relates to situations where no reasonable control procedure can achieve significant reductions in individual or collective doses.

It is all a matter of optimization, regardless of whether the situation is a practice or an intervention.

A.J. GONZÁLEZ: Regulators must first decide whether to regulate in a given situation. The decision should depend on whether regulation will improve radiation protection, and that depends on whether the exposures are amenable to control. In some countries, exposures in certain situations are considered not to be amenable to control; in others, the opposite view is taken.

If regulators decide to regulate in a given situation, they must apply the same principles as in other situations, regardless of whether it is a practice or an intervention, a distinction which, in my view, is in any case unhelpful. Their aim must simply be to reduce exposures.

C.J. HUYSKENS: Even if control of occupational exposure to natural radiation can be made compatible with controls of occupational exposure to artificial radiation (and I believe that it can), that does not in my view mean that the entire radiation protection system must be applied in every situation. The important thing is that the objective of protection against natural radiation and that of protection against artificial radiation should be compatible. J. van der Steen made it clear that the approach to achieving the radiation protection objective in a situation which has existed for a long time may well differ from the approach called for in a new situation.

When making her oral presentation, M.A. Waters seemed to be very impressed by the EU's approach to dealing with the question of the radiation exposure of aircrews. I am not so impressed by it. What have we achieved by calling aircrew members 'radiation workers' and recording their individual doses in greater detail than we record the doses received by workers in the nuclear industry? In my view, the only achievement has been an increase in the attention paid to the issue of pregnant aircrew members, and recording the individual doses of aircrew members is a waste of time and money.

Regarding the exemption criterion of 10 μSv/a, we should not forget that it was meant to be used in deciding whether a public exposure problem existed, in other words, an environmental problem, and not in deciding whether an occupational exposure problem existed. A long standing or a new practice constituting a public exposure problem does not necessarily at the same time constitute an occupational exposure problem.

What we need to focus on is what we want to make compatible, rather than how we want to achieve compatibility.

K. SCHNUER: Regarding the radiation protection of aircrews, I would mention that 12 years ago the aircrew representatives pressed very hard for something to be done in that area, arguing that, on average, aircrew members were receiving higher doses than workers in the nuclear industry. Among the things which they demanded was monetary compensation for doses received and exposure reductions through cuts in working (i.e. flight) hours. We radiation protection specialists were faced with the aircrew representatives on one side and the airline representatives on the other. The result of the negotiations was a compromise. The compromise entails an administrative burden for the airlines, but only a minor one — that of recording the doses of aircrew members. The recording of doses gives the aircrew members a kind of assurance that something is being done for them.

C.J. HUYSKENS: Of course, civil aviation is a very safe industry. What I am really concerned about are the radiation risks in industries that are generally unsafe, for example, the mining industry in some countries.

S. VAN DER WOUDE: As I mentioned in Topical Session 6, in South Africa we have an exclusion level of 0.2 Bq/g for each radionuclide. This is not the background activity concentration in South Africa. What happened was that we carried out a kind of generic optimization study and arrived at an exclusion level not so low that all radioactive material would have to be included within the regulatory system and not so high that radioactive material of real concern would be excluded.

Although we believe that the exclusion level of 0.2 Bq/g for each radionuclide is in accordance with the International Basic Safety Standards, we would still welcome an international consensus on exclusion levels, since South Africa has had major trading problems due to its exclusion level, with large quantities of minerals being sent back from abroad and even with people being arrested.

K. ULBAK: Regarding the title of this Round Table, I think that control of occupational exposure to natural radiation is already quite compatible with controls of occupational exposure to artificial radiation.

Let us consider a common situation involving artificial radiation. The staff working with a radiotherapy source in a hospital are subject to regulation. In neighbouring workplaces, however, there are staff who may well receive doses from that source of up to, or even above, 1 mSv/a. They should be informed of that fact and perhaps monitored, and the same approach should be adopted when we identify workplaces where the doses due to natural radiation could exceed, or even just approach, 1 mSv/a.

In my view, a great deal has been accomplished in Europe. We have ensured that workers are informed about the radiation risks which they may encounter in the workplace and we have ensured that pregnant aircrew members have the same protection as pregnant women in ground level workplaces involving exposure to artificial radiation.

With regard to mining and various processing industries where doses can exceed 1 mSv/a, we issue guidance. I think, however, we should in addition press for radiation protection to be part of normal worker protection, along with measures such as dust abatement. In my view, that is the best way of achieving dose reductions.

E. AMARAL: This discussion has taken place against a background of economic and social interests. We, as regulators, can play around with numbers (risk estimates, etc.) and concepts (practice, exemption, etc.), but we must not play around with our obligations, one of which is to ensure that people do not incur unnecessarily high doses. However, that does not mean that we must control everything, that would be a waste of money.

As regards exemption levels and dose limits for practices or work activities, I do not think it is fair to apply those same criteria to members of the public, even in the case of people living near a place where there has been an intervention after an incident.

G.C. MASON: I think we know what our objective is, but we are still struggling with the problem of how to achieve it. I hope that this discussion will have helped us.

ROUND TABLE 4

WHAT ARE THE MAIN PROBLEMS IN OPERATIONAL IMPLEMENTATION OF RADIATION PROTECTION STANDARDS?

Chairperson: **I. Othman** (Syrian Arab Republic)

Round Table Members: **H.-H. Landfermann** (Germany)
Liu Hua (China)
P.M. Sajaroff (Argentina)

Scientific Secretary: **M. Gustafsson** (IAEA)

Round Table Presentation

P.M. Sajaroff
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This Round Table deals with the main problems in the operational implementation of radiation safety standards. I will not reiterate previous comments that were made in the other sessions and round tables but I will make a very wide and open presentation in this regard. Since we are discussing problems, I will present this from a general perspective and not just from a national one. So, in my experience problems result from two main causes: problems at the organization level and those due to unsolved or pending technical aspects.

The first group concerns organizational problems. In my view, according to my experience, and not only in Argentina, the basic problems are usually related to ineffectual regulatory performance. Second, non-appropriate technical competence in radiation protection and safety matters at all levels; that means at worker, employer and regulatory levels. However, legal competence is a necessary condition but not a sufficient one. The basic point here is knowledge — knowledge and experience — and we can have a very formal and appropriate background of real competence, real instruments, but if we don't have real technical competence the results will not be very satisfactory. Another topic concerns the inadequate discharge of managerial responsibilities at the operational level and following on from this, a weak safety culture and a lack of an effective quality system.

The operational implementation of radiation protection standards is often more formalistic than realistic. So in this type of case, for any given country, a commitment at a very high political level is a necessity.

The second set of factors associated with such problems are unsolved or pending technical factors and in my view the issue with the complex system of exemption, clearance and action levels, particularly in the case of commodities, is to establish an adequate set of activity concentration levels for specific radionuclides, either natural or artificial, for radiation protection priority action. This is for regulators. Other aspects, other issues are not a matter of concern for this meeting. Of course, achieving an international concensus for attaining this goal is essential; without one I don't envisage a solution being found.

Another item concerns the identification of priority sources. According to experience gained *globally*, not just in a few countries, the diversity and the number of accidents having, in most cases, severe radiological consequences demonstrate that the trefoil symbol seems to be, or actually is, ineffective as a warning label to those persons unaware of the involved risk. This is also true of workers not working with radiation sources. There are a number of examples where workers not performing their tasks with radiation sources have been affected by radiation sources. The case of gamma radiography sources is one of the better examples. So, a better warning label is in my opinion a must, but the point is, which one? Again, achieving an international concensus is a necessity. Special consideration should be given to sources with a high potential for posing severe radiological consequences in the event that they are orphan or lost. Again, the case of gamma radiography sources is one of the best examples. In the case of small sealed sources, it is their very size that poses a challenge to design engineers. How to insert such a symbol on their suface? However, this is not a new challenge; in the 1980s, at least in Argentina, such identification was suggested and mentioned in a number of national and non-national, multilateral and international level meetings as a means of identifying such sources for gamma radiography, but it is clear that solutions to this case will not be readily forthcoming. Gamma radiography sources are not the only ones to have been involved in radiological accidents. Telecobalt therapy sources, for instance, and other types of source have similar problems with identification.

Another area of concern is that of paediatric diagnostic radiology. Despite the existence of specialist equipment for holding the patient during diagnostic studies, this invariably remains unused. This has clear radiological implications for nurses and comforters.

Once again, occupational exposure to natural radiation sources in non- nuclear industries was discussed and commented on in several papers presented at this Conference. Here, the issue is how and when to convince the various levels of management and stakeholders that an assessment of radiation exposures and working conditions needs to be systematically implemented. I don’t see a very quick and easy solution to this but action is really necessary.

Round Table Presentation

THE MAIN PROBLEMS IN THE OPERATIONAL IMPLEMENTATION OF RADIATION PROTECTION STANDARDS FOR OCCUPATIONAL EXPOSURE IN THE CHINESE NUCLEAR INDUSTRY

Liu Hua
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1. INTRODUCTION

The Chinese nuclear industry is about 40 years old. There are 11 power reactors in operation or under construction, 17 civilian research reactors in operation, 6 civilian nuclear fuel cycle facilities, 2 low level waste disposal sites and 25 temporary radioactive waste storage facilities located in urban areas. There are about 50 000 radiation sources used in industry, agriculture, and medical and science research. The regulatory body, the National Nuclear Safety Administration, was established in 1984 and a series of regulations, guides and standards on nuclear safety and radiation protection have been published since then. During this period, occupational exposure control underwent significant development, with progress made in radiation protection techniques and both regulations and management strengthened.

2. RADIATION PROTECTION REGULATIONS

The Chinese regulatory system of radiation safety has four levels:

(1) Act, issued by Congress:
- Environment Protection Act (1989).

(2) Regulation, issued by State Council:
- Regulations on Severance and Control of Civilian Nuclear Installations (1986),
- Regulations on Radiation Protection for Radioisotope and Irradiation Apparatus (1989),
- Regulations on Nuclear Accident Management in Nuclear Power Plants (1993),
- Regulations on Environment Protection for Construction Projects (1999).

(3) Implementation Rule or Department Rule, issued by responsible department agency of State Council:

—Regulations on Radiation Protection, GB-8703, (1987) SEPA;
—Rule on Radiation Environment Management (1990) SEPA;
—Rule on Management for Temporary Storage Repository (1987) SEPA;
—Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources. To be jointly issued by SEPA, MOPH and SCSTID. These standards will replace GB-8703.

(4) Standard or safety guide, issued by the responsible department agency of State Council.

There are tens of technical standards and safety guides on radiation protection, radiation environment and radioactive waste management in China. These guides and technical standards describe the detailed technical requirements and methods used to ensure radiation environment safety in siting, construction, operation and decommissioning of the nuclear installations, radiation source safety and radioactive waste management. The guides and technical standards deal with the technical requirements and limits on radioactive effluent release, radiation environment monitoring, radiation protection of the public and the environment, radioisotope safety, transportation of radioactive substances and radioactive waste disposal, etc.

3. IMPLEMENTATION OF OCCUPATIONAL RADIATION PROTECTION STANDARDS

The implementation of occupational radation protection standards involves several actions:

(a) Improvement of occupational exposure management, comprising: inspection and audit, including routine and special field inspections; performance review; examination of radiation protection personnel; implementation, review and improvement of good practices according to the ‘as low as reasonably achievable’ (ALARA) principle; facilitation of co-operation and experience feedback between facilities; establishment of dose control target.

(b) Dose monitoring, comprising: individual external dose monitoring, individual internal dose monitoring, working area monitoring, implementation of quality control programme for monitoring, improvement of entrance facilities in control area to increase capability for data treatment and contamination control, monitoring and control of weak penetrating radiation.

(c) Source term control for operational nuclear power plants, comprising: use of extensive measures of source term control during outage, including water chemistry control, cleaning, decontamination of equipment and components awaiting examination and repair; use of local temporary shielding, local ventilation and insulation, specific tools and remote tools for jobs with high dose rates.

The average annual dose for occupational workers in nuclear facilities in China has decreased progressively over the years (Fig. 1).

4. THE MAIN PROBLEMS IN THE IMPLEMENTATION OF RADIATION PROTECTION STANDARDS

There are several major problems that affect the implemention of radiation protection standards:

(a) *The legislation cannot meet the needs of radiation protection*: The Act, yet to be passed, on the prevention of radiological pollution will be the basic law on radiation protection in China. It has not yet been passed because of the debate concerning the functions of different government agencies. The Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources will be issued soon. However, related technical documents will be modified according to these standards.

(b) *Lack of independent inspection in radiation protection of radiation sources*: The National Nuclear Safety Administration is not regulating the whole process of protecting radiation sources, especially as regards production, use and sale. Compared with nuclear developed countries and the requirements issued by the IAEA on strengthening regulatory control of radiation sources, China needs to improve its regulatory system.

(c) *Improvement of old nuclear facilities with regard to radiation protection*: Some old facilities have neither good design nor adequate equipment, and the occupational dose is higher than in nuclear power plants. Experience feedback is not widely established and does not cover the whole process of design, construction and operation of facilities effectively. An efficient working management system for radiation protection is not established in some facilities.

5. FUTURE ACTIVITIES

There are plans to strengthen radiation protection by:

(a) Pushing the legislation process,

(b) Improving the licensing system for radiation sources,

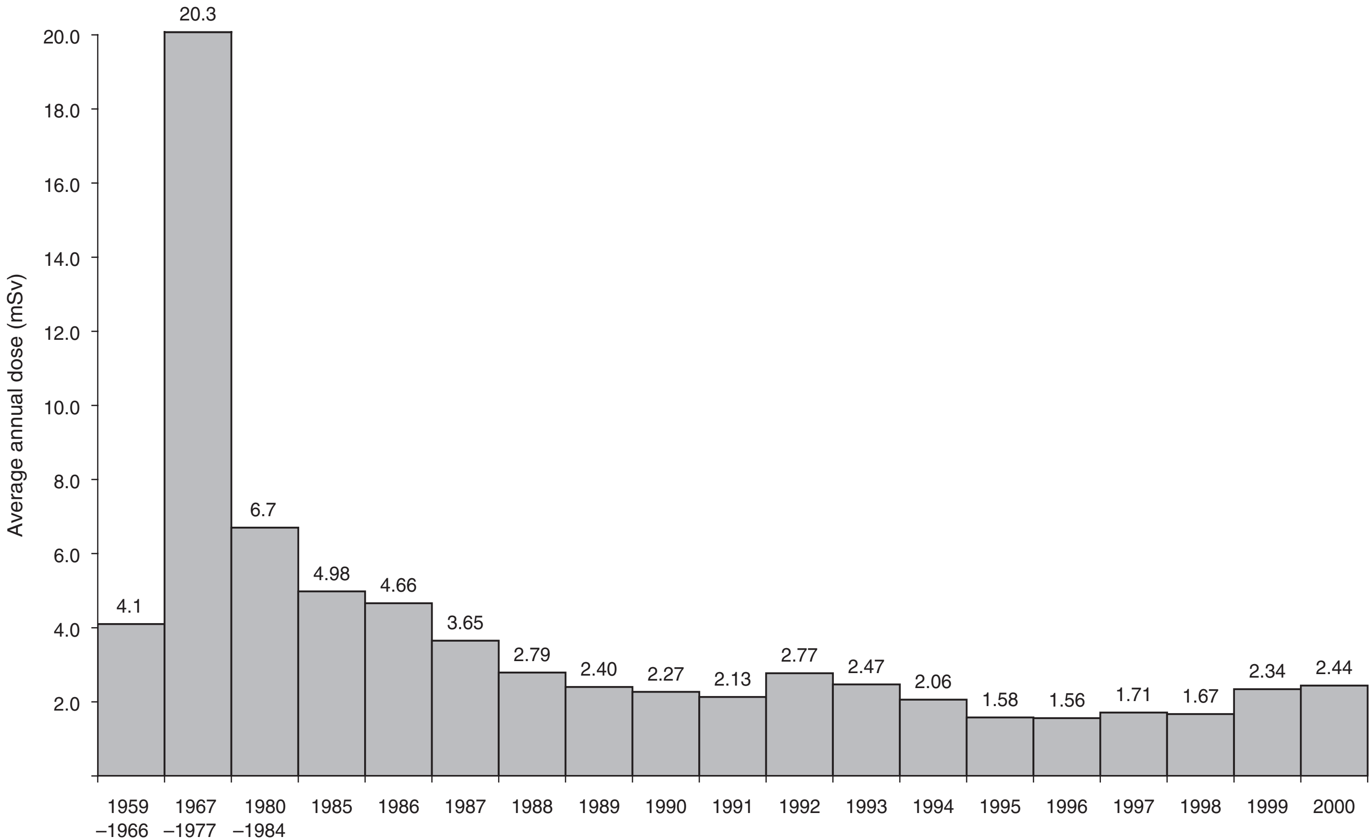

FIG. 1. Average annual occupational dose for Chinese workers (external exposure).

(c) Revising technical standards based on basic safety standards for protection against ionizing radiation and for the safety of radiation sources in China,
(d) Strengthening inspections,
(e) Strengthening environmental radiation monitoring,
(f) Promoting ALARA activities,
(g) Establishing the experience feedback cycle at different levels,
(h) Improving old facilities and introducing new techniques to reduce dose.

Round Table Presentation

I. Othman
Atomic Energy Commission,
Damascus, Syrian Arab Republic

In answer to the question, "What are the main problems in operational implementation of radiation protection standards", the author identifies several and these are summarized below.

The first problem is due to the fact that in most cases practices began a long time before the setting of standards. The standards were established after countries had widely applied the many applications of atomic energy and radioisotopes. This resulted in a lack of personal monitoring over a long time. It was years before any exposure record was established for radiation workers in developing countries. Moreover, if any accident happened, it was not reported officially. The right of occupational workers to compensation was lost. This affected the later practices as workers developed bad practices in handling radioactive sources and harmful work habits. Working without guides or standards will result in work difficulties with regard to changing habits or observing new rules and procedures.

The second problem is that in most developing countries, and for reasons of 'catching up', standards may not reflect the real situation of the country. This is mainly due to the translation of such standards from another language having been undertaken by non-specialists or persons inexperienced in the field of radiation practices. In some cases even the objectives may be lost in translation, not to mention that standards prepared for one region may not necessarily be applicable to another owing to differences in the governmental system or even to human attitudes.

The third problem in implementation is that relating to the preparation of the standards themselves. Most developing countries suffer a lack of well-qualified specialists. Also, owing to poor communication between users, administrators and scientists, the quality of the prepared standards themselves may be poor and they may contain many contradictions which, if discovered during their implementation, may lead to their not being applied. In developing countries, the composition of committees responsible for setting standards can create some problems. Some will be only members because they are holding high degrees. The feedback for applications and how it affects the revision of poorly or well written standards has a large impact on the quality of standards and their implementation.

The fourth problem in the implementation concerns the methods of how the standards documents are prepared and distributed. The language of the standards helps in clearing up any misinterpretation. The availability of all documents and the distribution and reminding of all occupational workers and other authorities of their availability will contribute to reducing the problems of operational implementation of standards.

The fifth problem in operational implementation of standards is the lack of experienced and qualified regulatory staff in most developing countries. Also, there is a lack of good training programmes on those parts of the standards relevant to operators, regulators and inspectors. We found that the education, training and safety culture of these groups are the main keys with which to overcome all the operational problems in the implementation of radiation protection standards.

Round Table Presentation

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Considerations on radiological protection always start off with discussions on concepts, principles and other basic assumptions. We are all aware of the fact that the International Commission on Radiological Protection (ICRP) is currently holding such discussions. They are useful for corporate radiological protection if they lead to rules and regulations which meet practical everyday requirements. In the topical sessions, papers have been presented on the implementation of 'basic safety standards' and corporate radiological protection in medical institutions, research institutions, technical plants and nuclear power stations. Some of these contributions were followed by discussions. In this presentation I would like to come back to some of the items raised in these discussions.

1. SPECIAL COMPENSATION ARRANGEMENTS

In the past it was standard practice for employees working with ionizing radiation to receive extra payment or extra vacation. In some areas this is still the case.

Thesis: *No compensation arrangements*

Basically, employers should be expected to provide a work environment that has a very low radiation risk. Above and beyond this, each individual employee is free to choose his or her place of work and by accepting a particular workplace an employee also accepts the professional risk involved.

Antithesis: *Compensation arrangements*

On the other hand, choosing a place of work in times of high unemployment is not always a matter of free choice. Also, there are still workplaces where there is a clearly increased level of radiation exposure and which can only be reduced by making substantial financial investments. Under certain circumstances special compensation arrangements could be opted for.

2. FEMALE EMPLOYEES

In principle, there is no difference between the radiation sensitivity of female or male employees. When defining limit values or other labour protection measures a difference between sexes should not be made. A special aspect, however, is the protection of unborn life.

Thesis: *Equal conditions for male and female employees*

Since women are no more sensitive to radiation than men they should be allowed to work under the same conditions as men. Pregnancies must be indicated to the employer, which has to provide a workplace that has lower levels of radiation exposure.

Antithesis: *Better protection for female employees in the workplace*

Since pregnancies are often recognized relatively late, workplace conditions for female employees must ensure little monthly radiation exposure. This applies in particular to the intake of radioactive substances, which remain in the body of females for a long time. Following this rule means that unborn life is sufficiently protected even if a pregnancy is not yet recognized. Given these circumstances, special protection for female employees should be opted for.

3. SPLIT RESPONSIBILITIES BETWEEN EMPLOYEES AND LICENSEES

It cannot be denied that there may be conflicts of interest between the employees and the licensee of a plant if radiological protection measures are to be organized at the workplace. As a rule, such measures are expensive and/or do not increase the productivity of a plant.

Thesis: *The licensee is in charge of organizing radiological protection in a plant*

A responsible manager will organize radiological protection in a way which ensures sufficient protection to employees.

Antithesis: *An appointed manager is in charge of organizing radiological protection in a plant*

An appointed manager in charge of radiological protection and in possession of far-reaching powers vis-à-vis the company management could also ensure that in cases of conflict employees are sufficiently protected with regard to increased radiation exposure.

4. DIFFERENT NATIONAL REGULATIONS BUT FREE MOVEMENT OF WORKERS

Given the general worker mobility which characterizes our time, workers who are subject to radiological exposure because of their occupation may work in different countries. This is particularly true of certain engineering professions in the nuclear industry. Owing to differing regulations in individual countries this may lead to problems.

Thesis: *National regulations apply*

The legal regulations of a country must be respected, even if workers from abroad work in that country. Workers have to adapt to the specific conditions under national legislation and must organize their work accordingly.

Antithesis: *National regulations should, as far as possible, comply with international standards*

In the area of radiological protection, a number of international organizations work on draft radiological protection standards. These standards should be incorporated into national legislation. Workers could thus work under similar conditions in different countries.

5. VALUE OF ALPHA IN OPTIMIZATION

For some time the ICRP has known about the three principles of radiological protection: justification, optimization and dose limitation.

When optimizing radiological protection measures, a comparison should been drawn up between the radiation levels prevented and the dose reduction costs. Alpha describes the monetary factor for the man-sievert equivalent.

Thesis: *An internationally defined value for alpha should be used to implement the optimization process*

Antithesis: *To achieve optimum radiological protection the principle of proportionality should be applied. The ICRP suggests that, "The protection can then be said to be optimised and the exposure to be as low as reasonable, economic and social factors having been taken into account."*

ROUND TABLE 4

DISCUSSION

F.J. MORALES: We, in Nicaragua, had great difficulties in starting with the operational implementation of radiation protection standards. In the first place, we had no such standards, and we had no regulatory body, only a law providing for the establishment of such a body.

We established a regulatory body with help from the IAEA, and then we drew on the IAEA for standards, some of its standards having been translated into Spanish. We also received, within the framework of the IAEA sponsored Co-operation Agreement for the Promotion of Nuclear Science and Technology in Latin America and the Caribbean (ARCAL), assistance from Spanish speaking countries such as Argentina, Chile and Mexico, and also from Brazil. In addition, we were helped by very advanced countries such as France, Germany and the USA.

It is not easy working with standards from a variety of sources, but we are grateful for the assistance which we received and hope that in 10–20 years' time we will be able to develop our own standards.

P.M. SAJAROFF: A country establishing radiation protection standards would do well not simply to take over the standards of other countries or of the IAEA as they stand, but rather to adapt such standards to its particular needs, even if this may involve a great deal of effort.

I. PRLIĆ: Following the break-up of the former Yugoslavia, Croatia found itself with a fair number of people experienced in the field of radiation protection. Nevertheless, it is participating in one of the IAEA's model projects for upgrading radiation protection infrastructure, largely in order to obtain help with the formulation of standards and regulations.

Because of the military activities in and near Croatia during the 1990s, we quickly established a radiation source database as we were very concerned about the fate of radiation sources in a war situation. Nevertheless, we now have a problem of illicit movements of radioactive material, especially across Croatia's maritime (Adriatic) border, and we are having to set up a radiation monitoring system as a countermeasure.

We have had no problems with the occupational radiation exposure of aircrews, but the ground staff at our main airports complained that they were receiving excessive doses from the X ray machines used in examining baggage, with the result that the airports in their entirety were declared to be controlled areas. It took me two years to convince everybody, including the Ministry of Health, that that was nonsense.

We have very good records relating to the occupational radiation exposures of workers employed within Croatia, but many Croatian workers, for example, industrial radiographers, have been employed abroad and we are having great difficulty in obtaining exposure data from their employers, who seem unwilling to enter the data in the radiation workers' 'passports'.

Another issue is the inclusion of national identity card numbers in radiation workers' passports. In my view, that is the best way of keeping track of radiation workers, but many people consider it to be 'undemocratic', so the Croatian Government is now struggling with the issue.

In the light of our experience with one of the model projects and of some of the matters I have just referred to, I would suggest that the model projects be expanded to include some element of education and training for senior decision makers.

I. OTHMAN: As with I. Prlić and his colleagues, we were experienced in the field of radiation protection when we started participating in one of the IAEA's model projects for upgrading radiation protection infrastructure. However, through the model project we have received very useful training and guidance.

S.B. ELEGBA: You do not have to have a nuclear power programme in order to experience a serious radiation incident or accident which can raise doubts worldwide about the peaceful applications of atomic energy. Such an incident or accident may well occur in a developing country with no nuclear power programme, which underscores how important the IAEA model projects for upgrading radiation protection infrastructure are in helping to ensure that the peaceful applications of atomic energy are not all rejected by the public.

K. SCHNUER: When talking about the operational implementation of radiation protection standards within a given country, one must consider, inter alia, the level of technical development of that country, its economic situation and its operational infrastructure, which includes things such as the arrangements for radiation protection education, training and information exchange. If all three are satisfactory, the country should not have any major problems with the operational implementation of radiation protection standards. If even just one of them is unsatisfactory, however, major problems will arise.

Another kind of problem on the horizon is connected with the tendency to shift responsibility for the operational implementation of radiation protection standards from regulators to operators, which often become overburdened by having to assume responsibility for things for which they should not be made responsible. The situation is sometimes similar to that where the manufacturer of a microwave oven is held responsible when someone dries his/her wet cat in the oven. In a number of cases, the responsibility has had to be transferred back to the regulator. Ideally, the regulator and the operator should be working hand in hand.

G.G. EIGENWILLIG: With regard to the employment of females in Germany, until two years ago pregnant women were not allowed to work in controlled areas or with unsealed radioactive substances and breastfeeding mothers were not allowed to work with unsealed radioactive substances. Now, there is a dose level below which employers can require pregnant women to work in controlled areas and/or with unsealed radioactive substances and breastfeeding mothers to work with unsealed radioactive substances. The change was introduced in order to help reduce unemployment among females, but most of the females questioned in a survey conducted by the Federal Ministry of the Environment, Nature Conservation and Reactor Safety have said that they would not wish to work in a controlled area or with unsealed radioactive substances if they were pregnant or with unsealed radioactive substances if they were breastfeeding.

O.K. AWAL: It is heartening to learn about the advances being made in the field of occupational radiation protection, but we must not be complacent. We know the limitations, especially those in developing countries such as Bangladesh. Moreover, we are operating in a world where, among other things, the technology is improving and safety perceptions are changing, and it is difficult for developing countries such as Bangladesh to keep abreast of this dynamic situation.

The IAEA model projects for upgrading radiation protection infrastructure have proved to be very helpful in this respect, not least for the feedback which they generate. In my view, however, in order to be fully effective they need to be strongly supported also by, inter alia, the ILO, WHO and EU.

C. SCHANDORF: Countries participating in the model project for upgrading radiation protection infrastructure in Africa have benefited greatly from it, particularly through the establishment of inventories of radiation sources with the help of the IAEA's Regulatory Authority Information System. Moreover, the various guidance documents issued by the IAEA have been very useful to some of those countries in shaping their control regimes.

K. MRABIT: In view of the complimentary remarks which have been made about the IAEA's model projects for upgrading radiation protection infrastructure, I would like to emphasize that one of the main reasons for their success has been the high level of governmental commitment. Implementation of the model projects did not start until senior representatives of the prospective participating countries had made such a commitment formally and the respective responsibilities of those countries and the IAEA were clear. The IAEA's approach in that regard proved to be a sound one.

In Topical Session 7, J.R. Croft referred to the difficulty of ensuring that useful guidance literature reaches those who would benefit from it. The IAEA is trying to overcome that difficulty by providing each Member State, via a focal point, with five copies of each IAEA guidance document as it is issued. Also, the IAEA recently posted on its website most of its safety standards, with supporting reports and technical documents. They can be downloaded free of charge.

Mention has been made here of 'qualified experts', 'radiation protection advisers', 'radiation safety officers' and so on. In that connection I would refer Conference participants to IAEA Safety Guide No. RS-G-1.4, entitled Building Competence in Radiation Protection and the Safe Use of Radiation Sources.

S. VAN DER WOUDE: In the field of occupational radiation protection, considerable use is made of UNSCEAR data. I would therefore like to see the IAEA helping to ensure that the data being provided to UNSCEAR by Member States are of the necessary quality, consistency and reliability.

In South Africa, we are having problems in complying with the ‘20 mSv/a averaged over five consecutive years’ criterion. The criterion offers welcome flexibility, but it is difficult to apply since the necessary checks are made only after five years. It is particularly difficult to apply in South Africa, with its large migrant mining workforce.

K. ULBAK: The question of where responsibility for occupational radiation protection should lie is an important one. In my view, it should lie with the senior management of the company, regardless of whether the company is a licensee, and should be part of the overall responsibility for worker safety. As regards the country as a whole, we should ensure that the necessary commitments are made at a high governmental level.

An international convention on the safety and security of radiation sources might be useful in that connection, even if many countries were reluctant to become parties because their radiation protection infrastructures were still inadequate. To such countries one might say that they would not be expected to comply with all of the convention’s requirements from the very outset; that they should demonstrate their goodwill by becoming parties and start working towards compliance after a few years with all the requirements.

F.I.M. NOLAN: There has been a radical change in Canadian companies regarding responsibility for occupational health and safety. Joint health and safety committees now report directly to the chief executive officer, who is personally liable for injuries incurred in the workplace.

With regard to the trefoil symbol for ‘radiation hazard’, I consider it to be inadequate and would like to see an international competition organized in which artists would submit new designs for a radiation hazard symbol.

I. OTHMAN: Under its Revised Action Plan for the Safety and Security of Radiation Sources, the IAEA is exploring the possibility of developing and implementing a universal system of labelling such that any member of the public is immediately aware of the dangers associated with hazardous radiation sources.

A.J. GONZÁLEZ: With regard to the radiation protection of pregnant workers, I would recall that in the International Basic Safety Standards, which contain a great deal of regulatory language using the auxiliary verb “shall”, it is stated that “A female worker should, on becoming aware that she is pregnant, notify the employer...” The auxiliary verb “should”, not “shall”, is used in this statement. The reason for the exception was concern about privacy; when the International Basic Safety Standards were being formulated, representatives of the nursing profession, among others, pressed for “should” rather than “shall”.

The resulting problem is this — if notification of pregnancy is not an obligation, how can one impose on the employer an obligation to protect the unborn child? This problem needs to be looked into.

ROUND TABLE 5

IS THERE A NEED FOR A MAJOR CHANGE IN ICRP RECOMMENDATIONS INVOLVING OCCUPATIONAL EXPOSURE?

Chairperson: **A. Sugier** (France)

Round Table Members: **J. Billard** (United Kingdom)
R. Czarwinski (Germany)
R.W. Davies (United Kingdom)
C. Schandorf (Ghana)
J. Valentin (International Commission on Radiological Protection)

Scientific Secretary: **M. Gustafsson** (IAEA)

Round Table Presentation

VIEWS OF THE ICRP

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1. INTRODUCTION

The short answer to the question "Is there a need for a major change in ICRP recommendations involving occupational exposure?" is "No". However, some changes are desirable in order to simplify the application of the International Commission on Radiological Protection (ICRP) system of radiological protection, and the practical implementation of the system has reached differing levels of sophistication in different countries. The most far-reaching changes under consideration will have little or no bearing on the particular issue of occupational protection against the deleterious effects of ionizing radiation.

2. THE CURRENT SITUATION

The 1990 system of radiological protection [1] was developed over some 30 years. Over this period, the system became increasingly complex as the ICRP sought to reflect the many situations to which the system applied. After 1990, a considerable number of further reports provided additional guidance. One such report merits special mention here, ICRP Publication 75 [2], which deals with the general principles of radiological protection of workers.

This report sets out very clearly the way in which protection should be organized. It emphasizes a number of issues of paramount importance, among them:

(a) The responsibility of the operational management;
(b) The responsibility of individual workers;
(c) The importance of education, training and renewed training;
(d) The similarity between radiological protection and general health and safety concerns in the workplace;
(e) The importance of utilizing a similar approach to radiation as with any other hazardous agent at work;

(f) The particular importance of collaboration between management and workers, in consultation with the regulator, to achieve good health and safety for all concerned.

2.1. Problems

The guidance given in ICRP Publication 75 is recent and well established. The advice given does not need major revision. Instead, the main problem is that its advice has not yet been implemented in all situations. Some problems that may occur include:

(a) An overemphasis on dose limit as the sole instrument of achieving acceptable standards;
(b) A ‘paternalistic’ attitude where insufficient responsibility is given to, and demanded of, workers involved;
(c) A lack of responsibility on the part of the operating management.

None of these possible problems are due to insufficient or inadequate recommendations from the ICRP or other bodies involved in radiological protection. Instead, to the extent that they exist, they are due to insufficient implementation of existing recommendations, and the way to achieve an improvement must be to *focus on the real problems*.

Because of this, the ICRP is considering ways to simplify and unify its current system of radiological protection, while retaining the international consensus on important quantities and values that provide the strength of the current system.

3. EMERGING NEXT RECOMMENDATIONS OF THE ICRP

Fundamental Recommendations of the ICRP are published every fifteen years or so, and the next Recommendations are expected around 2005. Publication on that time-scale is essential and would be necessary even if the Recommendations were identical to the 1990 version.

In order to maximize participation and achieve the best possible result, the ICRP opened a public debate at the very beginning of its own deliberations on if, and if so, how, its Recommendations should be amended in the forthcoming publication. This has generated considerable interest and many very helpful comments, and because the process is far from finished, many further developments are likely. However, it seems very probable at this stage that the new Recommendations will:

(a) Consolidate recommendations and guidance since 1990 into a unified set of comprehensive (and, hopefully, more comprehensible) recommendations;

(b) Place an even more explicit emphasis on the role of society in the justification of practices and interventions;
(c) Explain more clearly the special meanings of justification and optimization in the radiological protection of patients;
(d) Reflect a shift of emphasis towards protecting individuals, by first ensuring a minimum standard of protection, then optimizing protection such that all reasonable steps are taken to reduce exposures further;
(e) Clarify dosimetric quantities needed for protection purposes;
(f) Provide of a coherent philosophy for natural radiation exposures;
(g) Introduce a clear policy for radiological protection of the living environment.

3.1. Consequences in the occupational setting

Probably the most marked change will be the explicit attention to protection of non-human species. This, however, is not expected to have any bearing on the radiological protection of workers against occupational exposures.

Most of the other issues mentioned above do have implications for the radiological protection of workers, but are not expected to lead to dramatic changes.

3.1.1. Consolidation of recommendations into a unified set

This first issue above appears to have generated some concern in the radiological protection community, possibly due to some misunderstandings about the purpose. The overriding ambition is to achieve simplification, not modification. The current system of protection includes more than ten different types of limit, action level and other boundary quantities. The ICRP is now likely to propose a comprehensive set of protective action levels that provides a *minimum standard of protection*.

The ICRP would emphasize the importance of achieving an international consensus with regard to such quantities, and the intention is to carry over existing recommendations and guidance into the system. Thus, protective action levels are expected to refer to well-established quantities and numerical values, such as an effective dose of 20 mSv/a to a specially trained worker, but it will be possible to reduce the number of different definitions, names and values to indicate more clearly the analogies between different situations, and to demonstrate more plainly why and how various actions are recommended.

3.1.2. Justification

The ICRP already stressed in its 1990 Recommendations that justification of practices and interventions reaches far beyond the specific topic of radiological protection and therefore is of societal concern. Adding emphasis to this does not constitute a major change.

3.1.3. Radiological protection of patients

The radiological protection of patients is important and selected problems merit further guidance, but attention to the protection of patients will rarely affect occupational protection directly. In most cases, a consequence of improved radiological protection of patients will be a concurrent improvement in protection of medical staff. This will not reflect any policy change; it is simply a matter of actually applying the existing system as intended to workers in a medical setting.

3.1.4. Shifting emphasis towards the protection of individuals

The very utilitarian approach taken in the 1990 Recommendations highlights the needs of groups and populations by emphasizing optimization as the second tier of the system, with dose limits as a final, third step. This is logical but not always easily understood. A more egalitarian approach is now advocated by the ICRP, where protective actions ensuring a minimum standard of protection are a primary concern and are followed by further optimization to achieve the best level of protection under the prevailing circumstances.

In itself, this shift of emphasis will not necessarily lead to any change in the practical application of occupational protection or the final level of protection achieved for workers.

However, the optimization of protection has become too closely linked to formal cost–benefit analysis. The ICRP stressed in Publication 55 [3] that this is but one of many useful tools. The next Recommendations are likely to further emphasize this, and to underline the importance of co-operation between the operating management and the representatives and members of the workforce on the one hand, and the regulatory agencies on the other. This was a point also made in ICRP Publication 75.

The next Recommendations are likely to develop the explicit involvement of 'stakeholders' (including, in the present context, workers) in the determination of what is reasonably achievable. Again, this will not necessarily lead to any major change to the actual actions taken, but it will certainly increase the feeling of participation and personal responsibility in the radiological protection of workers.

3.1.5. Dosimetric quantities

The ICRP intends to remove some persistent difficulties with, and misunderstandings of, its dosimetric quantities by clarifying its definitions and specifying their application. There is no proposal to move away from the use of effective dose as currently defined, but there is a need to re consider the definition of detriment used to derive tissue weighting factors and the numerical values of these and of radiation weighting factors. The purpose is to achieve simplification and avoid certain spurious problems; in most operations there will be no major effect on the practical application of radiological protection for workers.

3.1.6. Natural sources of radiation

The next Recommendations are likely to incorporate, broadly speaking, the current guidance provided in ICRP Publication 65 [4] for radon, and to adopt a similar philosophy with regard to other sources of natural radiation, always with the basic proviso that controllable exposures only are taken into account. In terms of occupational exposure, this would mean a more unified approach, not the introduction of something new, and while there might be practical implications in a limited number of particular practices, the basic effect will be a simplification.

4. CONCLUSION

The current system of radiological protection as defined by the ICRP is logical but too complex. Its advice concerning occupational protection against the deleterious effects of ionizing radiation is basically sufficient and should be applicable with little change also under the next ICRP Recommendations.

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Round Table Presentation

VIEWS OF THE REGULATORS

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The International Commission on Radiological Protection (ICRP) offers its recommendations to regulatory and advisory bodies and provides advice to help management and professional staff with responsibility for radiation protection. The ICRP has no formal power to impose its proposals. However, legislation and regulations in most countries adhere closely to ICRP recommendations. The recommendations of the ICRP are based upon the fundamental principles and quantitative bases upon which appropriate radiation protection measures can be established.

The radiation protection system recommended by the ICRP in its Publication 60 is based upon:

(a) *Justification principle*: A practice or an activity that involves ionizing radiation exposure is justified if the anticipated benefit is greater than the risk incurred.

(b) *Optimization principle*: All exposures from justified practices shall be kept as low as reasonably achievable (ALARA), economic and social factors being taken into account.

(c) *Individual dose and risk limits*: Individual doses resulting from all relevant practices shall be subject to dose limits and risk limits in cases where potential exposures are likely.

To manage risks, three levels are usually distinguished: unacceptable risk, tolerable risk and acceptable risk. The aim of radiation protection is to reduce the radiation exposure level to below that designated as having unacceptable risk. When radiation protection is optimized, the residual risk level becomes acceptable. Any additional measure is ineffective both from economic and social points of view.

Regulatory limits adopted from ICRP recommendations are set such that continued exposure at a dose just above the limit would be unacceptable on any reasonable ground. Continued exposure at a level just below the dose limit might be tolerated but would not be welcome. Acceptable doses are those that are below the limit. Individual doses are only acceptable if they are optimized.

The optimization process involves answering the following questions. Are there any radiation protection measures likely to reduce occupational exposure? What is the gain in terms of avoided dose? What is the cost of the additional protection? Is it reasonable to incur costs in order to achieve gain? The answer to the last question depends on the sum that the undertaking is prepared to spend to avoid a collective dose of 1 man·Sv, i.e. the monetary value that is assigned to the man-sievert. This monetary value for different protection options is based upon an estimate of late radiation risks and the average levels of individual annual dose for radiation workers. Various countries and corporate utilities adopt different values; some use a set of values and some single value systems. Values recommended by authorities in countries are very often about 10% the level of corporate utility values. The determination of the monetary value of a man-sievert relies on the dose–effect relationship, which is assumed to be a non-threshold linear relationship.

The ALARA principle or procedure covers five steps:

(1) *Analysis of the problem*: Analysis of the exposure situation to determine the number of individuals exposed, the type of work undertaken and how the exposure occured.
(2) *Identification of radiation protection options*: Examination of all the possible ways of reducing exposure by acting on the sources and/or the protection system and/or the length of exposure.
(3) *Quantification of the options*: Evaluation of the effectiveness of each option in terms of the exposure reduction and cost.
(4) *Selection of the best option*: The available protection options are compared so as to select the optimum, which leads to the best balance between exposure reduction and cost using a reference monetary value for the man-sievert.
(5) *Sensitivity analysis*: To verify that the selected option is cost effective and appropriate.

What is the major change envisaged by the ICRP? Is it a major change in the dose–effect relationship (assumed to be a non-threshold linear dose–effect) and the probability of developing a health effect associated with a collective dose of one man-sievert? Whatever the change, an ALARA programme can still be used to obtain the best dose reduction option in a cost effective manner. As a regulator, any ALARA plan that enables management to reduce individual and collective doses with priority being given to the highest exposed groups will be acceptable.

The ICRP was set up to develop radiation protection strategies that are based upon scientific research and analysis of global data on the biological effects of ionizing radiation. It was not set up to create a revolution in the field of radiological protection. The ICRP issues recommendations at intervals of ten to fifteen years through its main committee and these are based on the work undertaken by task groups. In any case, a major change would take time to be incorporated into any well-managed regulatory control programme for the protection of workers from the harmful effects of ionizing radiation. An established regulatory authority would analyse the impact of any major change made by the ICRP before amending its own regulations, codes of practice, guides, etc., to make them compatible with the change and would develop appropriate implementation strategies for managing the accepted change.

Round Table Presentation

VIEWS OF THE EMPLOYERS

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1. INTRODUCTION

The aim of this paper is to present an employer's view of the recent trends in occupational radiation exposure and discuss their implications as to the effectiveness of the existing system of radiation protection. Future needs are considered from the perspective of those employers operating in a global context. The general conclusions do not support major changes, but a change in emphasis and presentation to give greater clarity for the benefit of all stakeholders. The views presented are derived from discussions within industry, but do not represent the views of any particular employer.

2. TRENDS IN OCCUPATIONAL EXPOSURE

Figure 1 shows trends in occupational exposure in the United Kingdom following the introduction of the International Commission on Radiological Protection (ICRP) Publication 26 recommendations into UK law via the Ionising Radiations Regulations (1985). There have been dramatic reductions in the number of workers exceeding whole body doses of 20, 15 and 10 mSv respectively. By 2001, only 0.07% of radiation workers in the UK exceeded 10 mSv. Most of these were in one sector — industrial radiography.

The focus on optimization was, to a great extent, in response to a requirement in the law for an investigation level (set at 15 mSv) which required that employers review the exposure conditions of the most exposed individuals and introduce measures to reduce dose. Much of the early reduction achieved was due to the relatively simple and inexpensive changes introduced to work practices and management systems. These have been referred to at this Conference as examples of 'win–win optimization', and they ultimately had an effect on the safety cultures of the organizations concerned. Later reductions required investment in plant and facilities. As the numbers of staff exceeding 15 mSv fell so the employers introduced their own lower investigation levels to continue the optimization process.

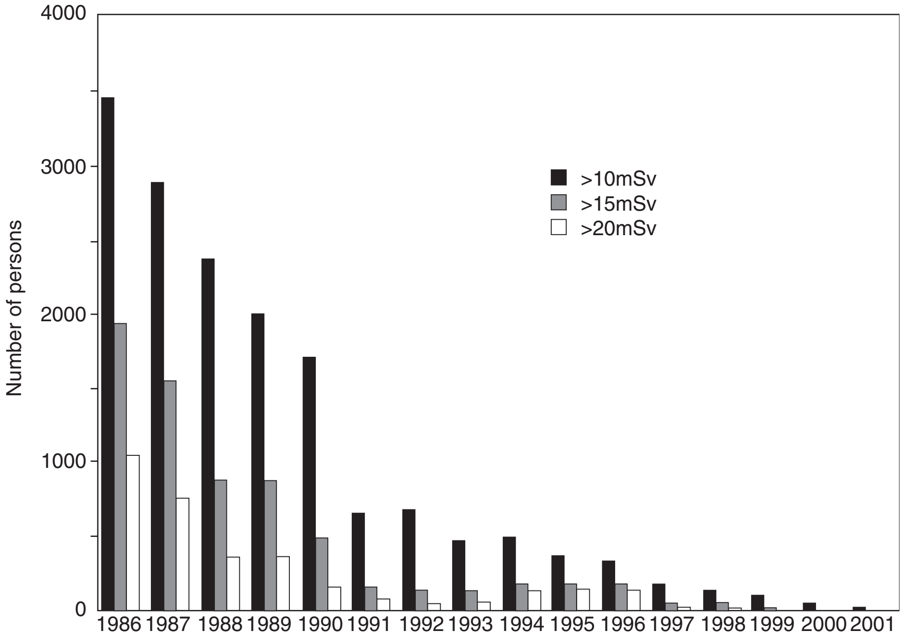

FIG. 1. Trends in occupational exposure in the UK. Data derived from the UK Health and Safety Executive's Central Index of Dose Information.

3. CURRENT SITUATION

Previous ICRP recommendations have clearly yielded positive results. Indeed, in some cases, it may be that doses are approaching ALARP (as low as reasonably practicable). However, the situation in some other countries is different, for example, the United States of America, which only adopted ICRP Publication 26 in 1993–1994, is not yet showing the same pattern of dose reduction, possibly because there is less application of the 'as low as reasonably achievable' (ALARA)/ALARP principles.

It is probably too early to witness the full effect of the ICRP Publication 60 recommendations as many countries in the European Union only incorporated the recommendations into national law two years ago and other countries have yet to do that.

There is also a move in the nuclear industry to decommission historic plant. There are significant uncertainties associated with such work and, even with optimization, there may be some increases in dose. For this reason, there is a need to retain the current flexibility in relation to annual dose limits which comes from the ICRP Publication 60 recommendations.

One area which employers find concerning relates to the pressure in some countries to reduce public exposures from levels which would technically be regarded as trivial — at the expense (potentially) of increased occupational dose. The impact of any perceived benefit in such reduction of exposure to the public will need to be carefully balanced against potential increases in occupational dose.

4. FUTURE NEEDS

There are a number of areas to consider when developing any new ICRP recommendations. Firstly, the globalization of business means that companies must expect scrutiny of their practices irrespective of where in the world they operate. They will need to be able to defend the standards they adopt, and to that end a basic set of standards from the ICRP, genuinely applied on a global basis, is a clear need.

Next, given that previous recommendations have tended to be complex in nature and that there are increasing numbers of 'stakeholders' in or associated with the field of radiation protection, there is a need for simplification. The protection system must be open and transparent and readily understandable to all stakeholders.

The focus should be on individual dose and the risks that the workers run must be acceptable and comparable to acceptable risks in related/similar industries.

Optimization is the key and must be promoted, particularly in those countries where the focus is more on dose limits. This approach could be supplemented by requiring that operators set improvement targets and have progress in achieving these monitored by the regulators.

Overall there is a need to encourage:

(a) *Proportionality*: For example, there should not be a situation where the workforce receives higher doses in order to reduce a public dose that is already trivial in radiological terms.
(b) *Cost effectiveness*: Namely, to ensure that 'reasonableness' is applied to judgements so that additional resources are not unnecessarily used for protection if they could be better used elsewhere (e.g. healthcare).
(c) *Practical guidance*: Needed to aid judgement and implementation.

5. CONCLUSIONS

The conclusions from the employer's point of view are therefore as follows:

(a) Should there be a major change to the basis of radiation protection? No.

(b) Could there be a benefit from a change in emphasis to make the system more open and transparent and to ensure resources are applied appropriately? Yes.

(c) The developing 'protective action level' system could certainly provide the basis because it could bring consistency to the way in which the radiological safety of workers and the public is delivered; exempting negligible exposure from control and retaining the focus on the individual and on optimization (ALARA/ALARP).

(d) If a 'backstop' of limits is required, then retaining the approach in the current recommendations could allow flexibility in dealing with the complexities and uncertainties of future decommissioning.

(e) There is merit in considering the control of collective doses for specific work groups.

(f) There will be a need for detailed practical guidance.

Round Table Presentation

VIEWS OF THE RADIATION PROTECTION PROFESSIONALS

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Confidence is an indispensable prerequisite for successful communication concerning the development of future recommendations in radiation protection. The process of confidence building is difficult. It requires a clarification of the different roles and interests of all parties involved, i.e. policy, economy, public and safety. The willingness to accept a new concept will be increased perceptibly if relevant persons or groups of persons (stakeholders) are already involved in the selection of alternatives. Radiation protection professionals are important partners in the process initiated by the International Committee on Radiological Protection (ICRP), discussing recommendations to come.

1. RADIATION PROTECTION PROFESSIONALS

There is no uniform view which is characteristic of radiation protection professionals; their background, priorities and interests are heterogeneous.

In general, the radiation protection professional is an adequately trained person who uses his/her technical or scientific experience and skills to protect human beings (and increasingly, the environment) against the harmful effects of ionizing radiation. These persons may be users of radiation in industry, medicine or science; they may be employed as radiation protection officers or consultants, or they may work within the regulatory or authority infrastructures. They may also be independent experts. In spite of the general goals they have in common, their priorities and their views may vary considerably.

In a scientific or research environment conflicts between research goals and safety aspects are common; scientists often rely on their experience, with only modest observation given to regulations. The views of regulators and authorities in many cases are guided by formal aspects and public perceptions. The economic or practical consequences of their decisions are generally of secondary importance. In the context of medical applications, the exposure of the personnel may be in conflict with the interests of the patient. The radiation protection officer in industry has to: convince the workforce that it is adequately protected, ensure that the legal requirements of the company are addressed, convince management of the need for protection measures, and satisfy the requests of the authorities.

With the exception of the protection of patients in medical radiation applications, the task of the radiation protection professional is complicated by the fact that very incommensurable aspects must always be balanced against each other: reduction of exposures against costs, safety against time consuming procedures, compliance with legal requirements against simplicity of processes, public concern against individual rights and interests.

The background of radiation protection professionals may also differ significantly. In most situations the integration of radiation protection into other processes (e.g. research or industrial development) is the most efficient way to ensure safety. For this purpose, preference may be given to a more general radiation protection professional with a physical science or technical background. In contrast, a few situations (e.g. decommissioning projects) may demand the use of a protection specialist exclusively trained and experienced in radiation safety matters.

2. PRESENT SITUATION

The present situation is characterized by:

(a) Well-established radiation protection systems which are, at least in Europe, based on the recommendations of the ICRP.
(b) Only few gaps requiring additional attention.
(c) A need for further harmonization across national borders.
(d) A decreasing public acceptance of technical radiation applications; in some countries this results in significant deficits in technical and scientific expertise.

Since the publication and implementation of ICRP Publication 60 in the 1990s, which is the basis for our current system of radiation protection, at least in Europe, the occupational exposure in different applications (such as the nuclear fuel cycle, industrial uses of radiation, medical uses of radiation and defence activities) is, in general, consistently decreasing. The average annual collective dose was reduced from 5490 man·Sv to 2700 man·Sv between the periods 1974–1979 and 1990–1994, even though the number of monitored workers increased nearly by a factor of two (to 4.6 million). The average annual effective dose for monitored workers was reduced from 1.9 mSv in the first observed time period to 0.6 mSv in the last.[1]

Most of the States have an appropriate regulatory infrastructure with a well functioning system of monitoring and managing the occupational exposure. All

[1] Data taken from the United Nations Scientific Committee on the Effects of Atomic Radiation Report 2000.

relevant parties (workers, employers, regulators) have come to an arrangement with its national implementation.

This complex system, growing up with the increasing use of ionizing radiation during the past fifty years may include inconsistencies. These problems and their extent have to be recognized and taken into consideration, e.g. the occupational exposure of personnel during the medical application of ionizing radiation such as interventional radiology or radiosynoviorthesis (use of beta radiation). As an example, in Germany partial body doses to a doctor's hands of up to 200 mSv per working day were measured during a radiosynoviorthesis procedure. Additional attention needs to be given to the occupational exposure caused by natural radiation sources or by the use of natural occurring radioactive material. Another example, again from Germany, concerned measurements taken in waterworks where workers incurred exposures of up to 0.8 mSv/a. Also, the balance between occupational exposure generally and exposure of the general public has to be discussed.

3. DEMAND FOR CHANGE?

In general, from the view of practical radiation protection work, the few new aspects concerning occupational exposure which have to be integrated into the present system currently do not justify a major change in ICRP recommendations.

With each change made to those recommendations which could have an effect on national legislation, there is the attendant danger of increasing overregulation in radiation protection. Such a process has to be avoided so as not to lose the beneficiaries' (workers and public) credibility in the radiation protection system.

This view seems to be supported by the vast majority of radiation protection professionals even if, as outlined earlier, there is a spectrum of interests and degrees of interaction with the ICRP. While the radiation protection officer in industrial applications is mainly interested in a simple and accurate control of occupational exposure, the scientists and regulators necessarily have to have a more fundamental understanding of the ICRP and its protection philosophy. Because of its credibility and dependability, authorities appreciate ICRP recommendations as providing a solid scientific basis for regulations which allow for an internationally harmonized protection system. In practice, the undisputed regulatory usefulness of existing internationally harmonized dose limits is but one example. This they currently do and therefore any proposed changes must clearly demonstrate in the draft stage some benefits in the practical application of the recommendations. A new system should not be implemented piecemeal; the revision of ICRP recommendations should include all publications relevant to the new system. It should be carefully examined with regard to their practicability and necessity for future recommendations. Important features for any new system of radiation protection regulation as seen by the radiation protection professionals would be simplicity, transparency and reliability.

3.1. Simplicity of the system of radiation protection

A new ICRP system of radiation protection should provide the scientific and logical bases in an understandable and simple manner such that radiation protection professionals, especially regulators, will easily be able to assign priorities and to ensure adequately the safety in the use of ionizing radiation.

Amongst other things, the number of detailed criteria which will be indispensable for the implementation of the concept into practicable, legally enforceable regulations should be limited, even from the viewpoint that limits are necessary.

3.2. Transparency of the system of radiation protection

Transparency means that a new concept and the following regulations have to be practicable, comprehensible and traceable, not only for the radiation protection professionals but also for the beneficiaries. This implies making an 'impact statement' or assessment of consequences, i.e. a consideration of the costs as well as the technical and administrative efforts for introduction, implementation and practical use.

Clarity is also a key issue. Precise and clear information is necessary; unsolved problems should be mentioned in an open manner and not veiled. Injustices and unnecessary expenditure in the implementation have to be avoided!

3.3. Long term reliability of the system of radiation protection

The main appeal from radiation protection professionals, especially after the incorporation of ICRP Publication 60 into national law, is the need for stability. For instance, in the past, regulations, and above all quantities and units, have been changed too frequently. Some of the changes made last time were far and away beyond the insight and comprehension of the common radiation protection professional, never mind the general public, and didn't really improve safety. Their effect was counterproductive, leaving many people confused and insecure. It takes time and effort to bring about a common understanding, which is not good for the reputation of radiation protection.

The viewpoint of all radiation protection professionals on the need for any changes of ICRP recommendations involving occupational exposures has already been expressed in one of the conclusions of the International Radiation Protection Association 10 forum and confirmed in a Swedish project, "Whatever revisions to the current system are proposed, these should be carefully 'road tested' for their application before being firmly adopted."

Round Table Presentation

VIEWS OF THE WORKERS

J. Billard
Prospect, London,
United Kingdom

I hope that it is not symptomatic of the radiological protection business that I am making a last minute unscheduled intervention of behalf of the workers. I wonder too whether the Conference should consider the fact that there are no facilities for organized labour or indeed the public to comment during the International Commission on Radiological Protection (ICRP) consultation process regarding its recommendations.

I have just a few points to make. As a non-scientific participant I can see that we have available accurate dosimetry which can be applied everywhere. This is a most important point. But a problem for the Conference is the different position of developed and developing countries and I would say straight away that I could not accept lower national standards of radiological protection simply to allow that State to catch up economically.

We have heard a lot during the Conference about the application of ALARA. Perhaps I could introduce something different, that standards should be 'AHARA' — as high as reasonably achievable. There is no point, however, in imposing criteria that will be ignored, so there may have to be a period of optimization between developing and developed countries. There is every evidence to show that we are here at this Conference to help each other and this may provide an example. But I did not see the causation probability calculations yesterday distinguishing between developing and non-developed countries in relation to the effect of dosages on the human being.

Those same calculations also made no distinction between human-made and what I have come to recognize this week as NORM radiation exposure, so it follows again that the worker in a western State's nuclear power plant should have the same standards as underground workers in other countries. This is just an example but at least the same philosophy driving those standards should be applied.

No one will argue against the protection of the unborn child and I am not sure that we have a complete answer to this — providing equal opportunities and at the same time ensuring that there is no harm even before a pregnancy is noticed let alone reported. I think more work is needed on this particular subject.

I liked the comment made earlier this week that few managers — or even chief executives — expect to receive a radiation dose in their office. I don't think anything was intended here by my scientific colleague but the need to consult, listen and take note of the radiation worker should be obvious. If it is not, then it should be written into the regulatory procedure as being necessary. After all, for each pair of hands engaged by an employer or an operator there is a free brain as well.

If the intention is to ‘simplify’ and to ‘unify’ the present system of ICRP recommendations and to ‘focus on real problems’ we can finish here today satisfied only if the situation of the worker, worldwide, in coal mine, nuclear plant, hospital, or wherever, is such that they leave their family at home and go to work and return to them safely day after day after day and without harm whatsoever. If that then needs major changes to the ICRP recommendations then so be it.

ROUND TABLE 5

DISCUSSION

R. COATES: If I correctly understood what J. Valentin said in his oral presentation, the ICRP is giving serious consideration to the idea of reducing the 20 mSv/a occupational dose limit to something like 10 mSv/a. That would be an enormous change and I see no compelling need for it. Recalling the debate which occurred over the change from 50 mSv/a to 20 mSv/a averaged over five consecutive years, I would advise the ICRP to proceed with great caution.

R.T. LOUW: Something which has bothered me, essentially a non-member of the radiation protection fraternity, about this Conference is that the participants seem to be generally agreeing with one another. If they are generally agreeing with one another, that suggests either that not enough objective thinking is taking place here or that the Conference topics have been worked over so thoroughly that all participants must agree with one another. As we do not live in an ideal world, insufficient objective thinking is probably the reason.

Paper IAEA-CN-91/6, Health effects following long-term exposure to thorium dusts: a twenty-year follow-up study in China, points to a major regulatory failure which deserves to be highlighted here.

In 1990, some 70% of rare earth processing was taking place in Europe and North America. Then, price competition from China and a rigorous tightening up of radiological controls led to the closure of the European and North American rare earth processing industry.

In the 1990s, there was an expansion of rare earth processing in China, where the observed number of lung cancer deaths among the dust exposed miners has (as shown in Table IV of the paper just referred to) been six times the expected number — a dramatic health impact. As far as the worldwide health impact of rare earth processing is concerned, perhaps a less rigorous tightening up of the radiological controls in Europe and North America would have been preferable.

C. ARIAS: J. Valentin said that the ICRP's 1990 system of radiological protection is complex. I would say that it is comprehensive, which is not the same thing. In order to apply the system, you need to have a good knowledge of physics, radiobiology and several other subjects, and a good understanding of the purposes and possibilities of radiation protection.

As far as future ICRP recommendations are concerned, I should be interested in learning whether there will be any change in the philosophy and proposed optimization strategies relating to potential exposures.

G.A.M. WEBB: The 20 mSv/a occupational dose limit is such an important feature of national and international regulations that I would urge the ICRP to think very carefully before proposing any real change to it.

Also, I would emphasize that a unified system for the control of exposure to radiation, whether artificial or natural, in the workplace would make it much easier for everyone to appreciate that uniform standards are being applied.

I should like the ALARA concept to continue being used, but for years I have been saying that decision aiding systems are not very difficult. When we buy a car, we are performing a complex multiattribute analysis in our heads — an example of practical optimization.

T.D. TAULBEE: I recently reconstructed the doses received by three individuals who were involved in the 1958 criticality accident at the Oak Ridge Y12 plant and were exposed to 600, 700 and 900 mGy of neutron radiation. When the radiation weighting factors in ICRP Publication 60 are applied and the photon radiation is taken into account, the doses received by those three individuals become 9, 11 and 13 Sv. Such doses are generally considered to be in the lethal range. However, those individuals, although exhibiting deterministic effects such as vomiting and hair loss, did not die of acute radiation syndrome. They developed cancers of various types 15–20 years later. I hope that, in re-examining its recommendations, the ICRP will consider the radiation weighting factors for neutrons.

I also hope that, in addition to examining the biological data which have become available since 1990, the ICRP will consider the accidents involving high neutron exposures which have occurred in the USA and elsewhere.

J. LINIECKI: With regard to T.D. Taulbee's remarks, I would recall that there is an ICRP recommendation concerning the deterministic effects due to various radiation types. The factors used in calculations of effective dose do not apply to high doses.

A.S. TSELA: The ICRP is concerning itself more and more with exposures to natural radiation, and is even looking into the effects of radiation on non-human species. In doing so, the ICRP should, in my view, decide whether it is simply extrapolating into a new area or embarking on something for which a different frame of reference is needed.

F.J. MORALES: The ICRP's recommendations are fine, but in developing countries such as Nicaragua we need something easier for use in, for example, risk calculations. We also need guidance publications that will help us to persuade people such as physicians and radiation workers to take radiation protection seriously.

A. SUGIER: There are IAEA guidance publications of the kind that I think you have in mind.

C. SCHIEBER: With regard to R. Coates's comments about the 20 mSv/a occupational dose limit, I would recall that in the International Basic Safety Standards, the European Union's basic safety standards and the ICRP recommendations we still have 50 mSv as a maximum annual dose and 100 mSv as a maximum five year dose. In my view, this is causing problems in particular because 100 mSv over five years is difficult to control, especially in the case of transient workers, and 50 mSv/a represents an unacceptable risk. If something must be changed, rather than a reduction of the occupational dose limit to something like 10 mSv/a there should be a decision to really set the limit at 20 mSv/a and not to have a maximum of 50 mSv/a.

S. VAN DER WOUDE: I agree with C. Schieber. A straight 20 mSv/a limit would represent a welcome simplification.

I would like to see protection against ionizing radiation in the workplace integrated with protection against other occupational hazards, but to that end the ICRP would, in my view, have to consult with those who deal with those hazards and try to unify the terminology used in the various disciplines involved.

I think everyone agrees that there should be no major changes to the ICRP's 1990 recommendations. Before any changes are made, however, thorough consideration should, in my view, be given to their likely practical consequences, with the involvement of all stakeholders.

M.T. BAHREYNI TOOSSI: The feeling here seems to be that any changes to the ICRP recommendations should be evolutionary rather than revolutionary. In recent years, however, J. R. Cameron and a number of other scientists have taken the revolutionary step of challenging the basis of the ICRP's reasoning with regard to the harmfulness of low level radiation. They have shown that some groups of workers have, after exposure to low level radiation, enjoyed healthier lives. Would anyone care to comment on the controversial question of hormesis?

A. SUGIER: The question is indeed controversial and there would be still greater controversy if we did not have the minimum level of protection resulting from implementation of the ICRP's recommendations, even if these represent a compromise.

R.T. LOUW: I think that the issue raised by M.T. Bahreyni Toossi is a very pertinent one and I regret that it was not raised earlier during this Conference.

V. CHUMAK: In personal monitoring, $H_p(10)$ is a very convenient operational quantity for use in the assessment of effective dose, but there are situations where its use results in underestimates. Some boundary conditions should therefore be set when it is being used.

A. SUGIER: That is an important issue. We need to be very clear about the meaning of such operational quantities.

G.G. EIGENWILLIG: With regard to M.T. Bahreyni Toossi's comment about groups of workers who have enjoyed healthier lives after exposure to low level radiation, I would remind everyone here of the 'healthy worker effect' — the result of workers being selected on the basis of a good health record and undergoing medical checks and, if necessary, treatment during, and even after, their working lives. I do not think that the ICRP should allow its strategy to be influenced by hormesis considerations.

G.P. DE BEER: Regarding the issues of amenability to control and exclusion levels, they relate mainly to public exposures and we would need a further conference in order to discuss them fully.

A. SUGIER: I agree. Those issues are like the issue of the scientific basis for the system of radiation protection, which many people here would understandably like to discuss but which is not among the topics on the programme for this Conference. In the new ICRP recommendations, there will be a ‘building block’ on the scientific basis, but there must first be discussions with the specialists, as in the case of UNSCEAR. We must not mix up the different issues, as everyone will stick to his/her point of view and we will not make any progress.

C.J. THORP: I agree with what G.A.M. Webb said about a unified system for the control of exposure to radiation. It is a question of comprehension for the layperson and hence the credibility of regulatory systems. In my view, whatever we do about natural radiation must be consistent with what we do about artificial radiation, for we are being closely watched by a nuclear industry that considers itself overregulated.

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Topical Session 4	K. FUJIMOTO	Japan
Topical Session 5	J. LINIECKI	Poland
Topical Session 6	K. ULBAK	Denmark
Topical Session 7	B.C. BHATT	India
Topical Session 8	A.P. PANFILOV	Russian Federation
Topical Session 9	D.J. BENINSON	Argentina
Round Table 1	W. BINES	United Kingdom
Round Table 2	A.C. McEWAN	New Zealand
Round Table 3	G.C. MASON	Australia
Round Table 4	I. OTHMAN	Syrian Arab Republic
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