Promoting Internal Exposure Management: The IAEA Present and Future Activities

Rodolfo Cruz Suárez and Monica Gustafsson

Division of Radiation and Waste Safety
IAEA, Vienna

Introduction

Occupational exposure due to radioactive materials can occur as a result of various human activities. These include work associated with the different stages of the nuclear fuel cycle, the use of radioactive sources in medicine, scientific research, agriculture and industry, and occupations which involve the handling of materials containing enhanced concentrations of naturally occurring radionuclides. In order to control this exposure, it is necessary to be able to assess the magnitude of the doses involved.

The International Atomic Energy Agency (IAEA) is, according to its statute, charged with establishing or adopting, in collaboration with other competent international bodies, standards for safety for protection of health and to provide for the application of these standards. Basic requirements for radiation protection against exposure to ionizing radiation of workers, members of the public and patients are given in the *International Basic Safety Standards for Protection against Ionizing Radiation and for the Safety of Radiation Sources* (hereafter referred to as the BSS), jointly sponsored by the Food and Agriculture Organization (FAO), the International Atomic Energy Agency (IAEA), the International Labour Organisation (ILO), the OECD-Nuclear Energy Agency (OECD-NEA), the Pan American Health Organization (PAHO) and the World Health Organization (WHO)[1].

The objective of the IAEA Occupational Protection Programme, within the Division of Radiation and Waste Safety, is to promote an internationally harmonized approach for optimizing occupational radiation protection through:

– developing safety standards for restricting radiation exposures in the workplace - in collaboration with the ILO - and for applying current occupational radiation protection techniques, and

– providing for the application of these standards through: the fostering of information exchange on occupational techniques in specific working environments, the promotion of education and training in techniques for occupational radiation protection and the rendering of services through the Information System on Occupational Exposure (ISOE).

Also, within the same division the Radiation Monitoring and Protection Services Section implements the relevant Radiation Protection Standards to IAEA premises and render services to harmonize the monitoring requirements established by the BSS, specifically the radiation dose measurements for the control of occupational exposure, the aim being the harmonized application of dosimetric quantities and techniques.

Comprehensive guidance is provided through development of safety related documents- Safety Standards and Safety Reports. Additional valuable information appears in the Technical Report Series, or as cost free material, such as TECDOCs and Practical Radiation Manuals.

Direct support for application of these guidelines and recommendations to meet specific needs is provided to individual Member States, or regionally or interregionally through the Agency's Technical Cooperation programme. Such support is in the form of expert missions; national, regional and interregional training courses; fellowships for out of country training; and/or provision of equipment and supplies. On a limited basis, work may also be supported through small research contracts usually through Coordinated Research Programmes (CRPs) which are organized to address specific technical questions. In the area of occupational radiation protection, this approach has most commonly been used to conduct various kinds of dosimetry intercomparisons.

The aim of dose assessment for internal exposures is to obtain estimates of committed effective doses or committed equivalent doses to individual organs or tissues from monitoring data. The latter comprise measurement data on levels of radionuclides in the whole body or in organs and tissues, or of their rates of excretion, or on levels in the working environment, that can be used as a basis for assessing intakes and for relevant dose calculations. The purpose of this paper is to present the current and future IAEA activities in support of management of internal occupational exposure in the IAEA Member States.

Safety Standards

Developing new standards for nuclear, radiation, waste, and transport safety - and the revision of existing ones - are high-priority activities of the IAEA and its Member States. In 1996 a renewed uniform preparation and review process was introduced, covering all areas in which the IAEA establishes safety standards. Following upon the introduction of this process, two new series of safety-related publications were established, namely the Safety Standards Series and the Safety Reports Series. The purpose is to separate those IAEA safety standards publications which spell out safety objectives, concepts, principles, requirements and guidance - as a basis for national regulations, or as an indication of how various safety requirements may be met - from those publications which are issued for the purpose of fostering information exchange in safety.

The Safety Standards Series comprises three levels of documents: Safety Fundamentals, Safety Requirements and Safety Guides. The Safety Standards relevant to general Occupational Radiation Protection are given in Fig 1.

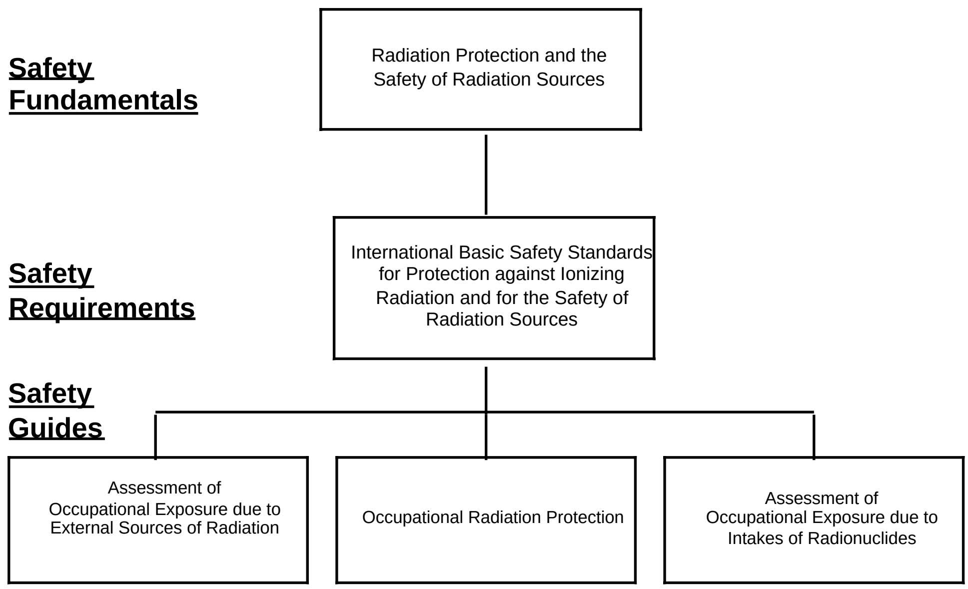

FIG. 1. Hierarchy of IAEA safety standards for general occupational radiation protection

The Safety Fundamentals, *Radiation Protection and the Safety of Radiation Sources* [2], explain the approaches to radiation protection and safety for persons in senior political or regulatory positions and persons who, although not safety specialists, make decisions relating to the uses of radiation in medicine, industry, agriculture and other areas.

The Safety Requirements, the BSS, deal with the basic requirements which must be met in order to ensure the safety of particular activities. These requirements are governed by the basic objectives, concepts and principles presented in the Safety Fundamentals documents. The written style, with “shall” statements is that of regulatory documents so that the Safety Requirements may be adopted by States, at their own discretion, as national regulations. The BSS, which were first published in English in 1996, establish basic requirements for radiation protection and safety, specify obligations and responsibilities and set out the requirements for application to practices and in intervention situations.

A set of three Safety Guides concerning the application of the BSS to the control of occupational exposures have been developed in a co-ordinated fashion as indicated by their related titles. They are co-sponsored by the International Labour Office (ILO) and were published in Autumn 1999. The Safety Guides documents contain recommendations, with “should” statements.

The Safety Guide on *Occupational Radiation Protection* [3] deals with the overall implementation of the requirements in the BSS, giving general advice on the exposure conditions for which monitoring programmes should be set up to assess radiation doses arising from external radiation and from intakes of radionuclides by workers. This Safety Guide addresses the technical and organizational aspects of the control of occupational exposures, in situations of both normal and potential exposure. The intention is to provide an integrated approach to the control of normal and potential exposures due to external and internal irradiation from both artificial and natural sources of radiation.

While the supplementary Safety Guide on the *Assessment of occupational exposure due to external sources of radiation* [4] contains guidance on establishing monitoring programmes for external exposure, the second supplementary Guide on *Assessment of occupational exposure due to intakes of radionuclides* [5] is of primary interest for this Workshop. This Safety Guide addresses the assessment of exposure due to intakes of radionuclides in the workplace. It presents the main considerations for monitoring for internal exposures both in routine and accident situations, using direct and indirect methods. It also introduces monitoring of levels of radionuclides in the working environment as a basis for assessing intakes. The biokinetic and dosimetric models needed for more specific estimates of doses to individuals, to be used in case of accidents or incidents, or when operations could result in doses approaching regulatory limits, are also presented.

While the recommendations in these three Safety Guides are intended for regulatory authorities, they will also be useful to employers, licencees and registrants, to management bodies and their special advisers, to health and safety committees concerned with the radiation protection of workers and to those responsible for the operation of individual monitoring services. It is intended to publish these three Safety Guides together with the BSS and the Safety Fundamentals on diskette or CD-ROM as an interlinked set of searchable documents.

Safety Reports and other material

The Safety Guide on *Assessment of occupational exposure due to intakes of radionuclides* is to be supported by three Safety Reports as presented in Fig. 2.

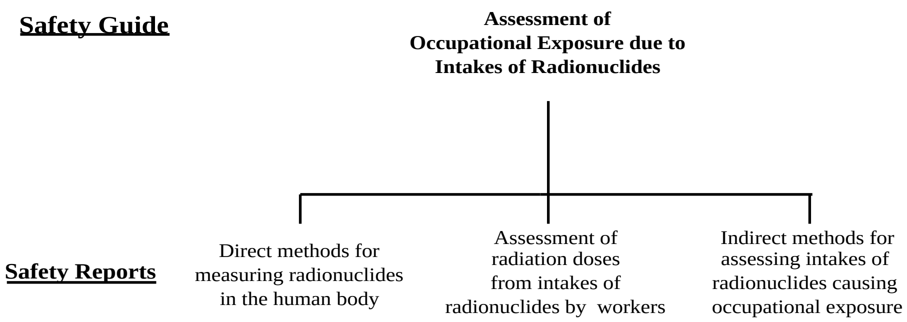

FIG. 2. IAEA Safety Guides and Safety Reports promoting internal exposure management

The Safety Practice on *Direct methods for measuring radionuclides in the human body* [6] , which would now be referred to as a Safety Report, was published in 1996. It provides information on the establishment and operation of facilities for the measurement in the whole body or in organs and tissues by direct methods, both in general application and in a range of specific situations. The emphasis is on measurements of body radioactivity made in programmes of internal dosimetry for occupationally exposed personnel, or in investigations following incidents. This Safety Practice describes the conditions for using direct methods for measuring radionuclides in the human body, outlines the available techniques of investigation and discusses the analysis of data. Eight Annexes contain more detailed descriptions of different methods of investigation for specific radionuclides as well as mixtures of radionuclides.

The Safety Report on *Indirect methods for assessing intakes of radionuclides causing occupational exposure* is in the process of being published. It is intended to assist in the setting up and operation of an indirect monitoring programme for workers who may come into contact with the radionuclides concerned. The Safety Report gives technical information on the collection and analysis of, mainly, biological samples used to estimate intakes of radionuclides, principally by measuring their rates of elimination from the body. It also provides information on the analysis of physical samples that can be used for estimating intakes, such as the measurements of airborne radioactive material. The Safety Report considers the sources of samples available for indirect monitoring of internal exposure, gives guidance on the choice of appropriate samples as well as information on methods of sample collection. It discusses the various measurement techniques available and methods of sample analysis. Nine Annexes are provided that describe detailed analytical procedures that have been developed by various laboratories for particular sources and samples, for which indirect methods are a primary means of estimating intakes.

These two publications provide advice on measurements of levels of radionuclides in the whole body or in organs and tissues, or of their rates of excretion, or on levels in the working environment. It is important to remember, however, that internal doses are usually not directly measurable; rather, they are computed by the application of biokinetic and dosimetric models to the results of direct or indirect monitoring measurements. Therefore, a third Safety Report on *Assessment of radiation doses from intakes of radionuclides by workers*, which is still under development, will present the main considerations for dose assessment in both routine and accidental situations. This Report will offer practical advice on the interpretation of measurements in terms of the amount of radioactive material taken into the body and the associated radiation doses. The purpose of this Safety Report is to provide persons charged with the responsibility for monitoring internal exposure of workers with comprehensive guidance on the methods for assessing committed effective doses from intakes of radioactive material.

A further IAEA document on *Dosimetry services for individual monitoring of occupational exposure from intakes of radionuclides* is being developed to support those persons concerned with the planning, management and operation of monitoring programmes and those involved in the design of equipment for use in internal dosimetry services and in workplace monitoring.

In addition to these Safety Reports and other related documents, published or in the developing process, the IAEA is also providing free of charge Practical Radiation Technical Manuals, designed to provide guidance on radiological protection for persons who have a responsibility to ensure the safety of employees working with ionizing radiation. Two of these deal with *Personal monitoring* [7] and *Workplace monitoring for radiation and contamination* [8].

Training

Education and training are basic elements in the Agency's programme on Radiation Safety. In the field of occupational protection, Agency training has been focused on the design, implementation and management of individual monitoring programmes covering all aspects related to the assessment of occupational exposure from external radiation sources and intake of radionuclides. Target countries for these training activities are developing countries with dosimetry services responsible for assessment of external and/or internal exposure for workers occupationally exposed to ionizing radiation. Several regional training courses have been carried out. While in West and East Asia, Africa and Latin America the focus has been on external dosimetry, both aspects were covered in a recent training course in Europe.

The training courses consist of lectures, demonstrations, practical work sessions and exercises with discussion sessions. Emphasis is given to basic concepts, dosimetric quantities, equipment characteristics, calibration, data interpretation and dose assessment methods. Management, administration and quality assurance within the Individual Monitoring Programme are also discussed. A course with this structure lasts for two weeks, one week devoted to external dosimetry and the second to internal dosimetry.

As mentioned above, three Safety Guides on Occupational Radiation Protection were published in 1999 and several related IAEA documents are close to finalization. As a part of the Agency's activities to facilitate comprehensive training programmes, a strategy for training on occupational radiation protection will now be formulated. This strategy will include proposals for training courses: their length and organization (balance between lectures and exercises), target audiences (regulators and/or users) and syllabi including practice specific scenarios and examples. Based on this strategy, training material for modules for general training on occupational radiation protection as well as for modules for practice specific training will be developed.

Intercomparison exercises

Extensive tables of dose per unit intake have been published by the ICRP and in the BSS. However, these are default values based on assumptions about the intake parameters that may not be valid in the real case. Determination of the radionuclide intake and the resulting internal dose can, therefore, be approached in many different ways, depending on the amount and quality of the data, the skill of the dosimetrist, computational tools available, and the assumptions made. When a set of bioassay data is given to two different dosimetrists, it is likely that these data will be interpreted differently, that different methods and dosimetric models will be applied, and therefore different numerical solutions will be obtained. Thus, it is important for laboratories dealing with internal dosimetry to undergo performance testing procedures to demonstrate the correctness of the methods applied and also the consistency of their results with those obtained by other laboratories.

Several intercomparison exercises were organized already at national or international levels [9-15]. These previous intercomparison exercises revealed significant differences in the approaches, methods and assumptions, and consequently in the results. This underlined the importance of this kind of intercomparison programmes as a key element of the harmonization process. The previous studies, however, were organized only for institutes either in Europe or the United States. Australia and countries in Africa, Asia, and Latin America were not represented in these studies.

In 1996 the IAEA therefore launched a Coordinated Research Project on *Intercomparison and Biokinetic Model Validation of Radionuclide Intake Assessment.* This intercomparison had a broader participation and the following objectives:

– to provide possibilities for the laboratories to check the quality of their methods;
– to compare different approaches in interpretation of internal contamination monitoring data;
– to quantify the differences in internal dose assessment based on various assumptions;
– to provide a forum for broad discussion of the results and methods which could help in more consistent interpretation of monitored data.

A total of 26 institutes from 22 countries plus the IAEA laboratory were invited, and 25 institutes actually participated. Nine realistic study cases were prepared. The test scenarios designed were based on either real data or artificially generated data. The cases include different radionuclides and also range from simple straightforward cases to complicated cases with different exposure conditions. The following study cases were offered to the participants:

Case 1: ^{3}H (HTO), single intake, pathway not specified
Case 2: ^{45}Ca, time and duration of intake unknown, ingestion
Case 3: ^{60}Co, single intake, inhalation
Case 4: ^{90}Sr/Y, intake conditions completely unknown
Case 5: ^{125}I, multiple intakes, inhalation
Case 6: ^{192}Ir, single intake, inhalation
Case 7: $^{238/239}$Pu, multiple intakes, inhalation
Case 8: $^{239/239/240}$Pu and ^{241}Am, single intake, inhalation
Case 9: ^{241}Am, single intake, inhalation

The nine test cases used in this intercomparison cover a wide range of exposure scenarios. In terms of time and duration of the intake, the test cases cover single and multiple, but not chronic intakes. In some cases (particularly the cases based on real exposure scenarios) not all the necessary information is known, and consequently the participants have to make different assumptions on the time and duration of the intake.

In terms of the routes of intake, both inhalation and ingestion are covered. In some cases, particularly those based on real exposure scenarios which do not have all the needed information, the participants have to make assumptions on which route of intake to consider. There is no test case in this intercomparison, however, for direct skin/wound absorption. This route is not that uncommon in accidents and should be considered in selecting test scenarios for future intercomparisons. In addition, cases involving different intake routes simultaneously should also be considered.

For the modes of intake, both single and multiple intakes but, as already mentioned, not chronic intakes are covered when designing the test cases. The participants, however, have made assumptions on the modes of intake including all these situations.
A unique feature of this intercomparison is that some of the test cases are artificially generated instead of based on actual exposure scenarios. Artificially generated data provide advantages such as better control of the amount of information available to the participants. All necessary information such as the time and the duration of the intake, the route of intake, the amounts of intake, biokinetics, the uncertainty in the measurements, and the resulting doses are also known to the organiser.

In setting up the test cases, it was assumed that the participants have all the necessary training and the tools to solve the cases. A lower response rate for more complicated cases may be attributed to the fact that some tools are not available to some participants. There is also some concern that some participants are using the newer ICRP dose factors with the older biokinetic models. This may be due to a national requirement or a desire to use the latest available information to solve the cases. However, the use of the dose factors should be consistent with the choice of the biokinetic models. It is important to point out that computational tools for applying the more recent models are not widely available yet. As a result, the mixed use of different models and dose factors can lead to results which are not scientifically based and also lead to greater inconsistencies as shown in a few cases. This issue is viewed as a temporary phenomenon because it is expected that computational tools for implementing the more recent biokinetic models will be more readily available in the near future.

There is also the issue of the confusion of the concepts. While the IAEA and organisations such as the ICRP are using the concept of effective dose, many participants are not. Therefore, many participants reported the resulting dose as the committed effective dose, E(50), while some were reporting the dose as the committed effective dose equivalent. Technically these are different concepts and cannot be compared with each other. However, this issue is beyond the scope of this intercomparison. For the purpose of the intercomparison they are treated as the same physical quantity.

Interests in other radionuclides than the ones covered in this intercomparison have been pronounced, such as those involved in the nuclear fuel cycle, those used in nuclear medicine or biomedical research (e.g., ^{32}P, ^{131}I), or those that are naturally occurring (e.g., thorium). Cases involving these radionuclides could be considered in future intercomparisons.

The results of the Co-ordinated Research Project on *Intercomparison and Biokinetic Model Validation of Radionuclide Intake Assessment* were published in 1999 [16]. An example of the evaluation and the presentation is illustrated in Fig. 3 and Fig.4 for Case 1, dealing with single intake of ^{3}H (HTO).

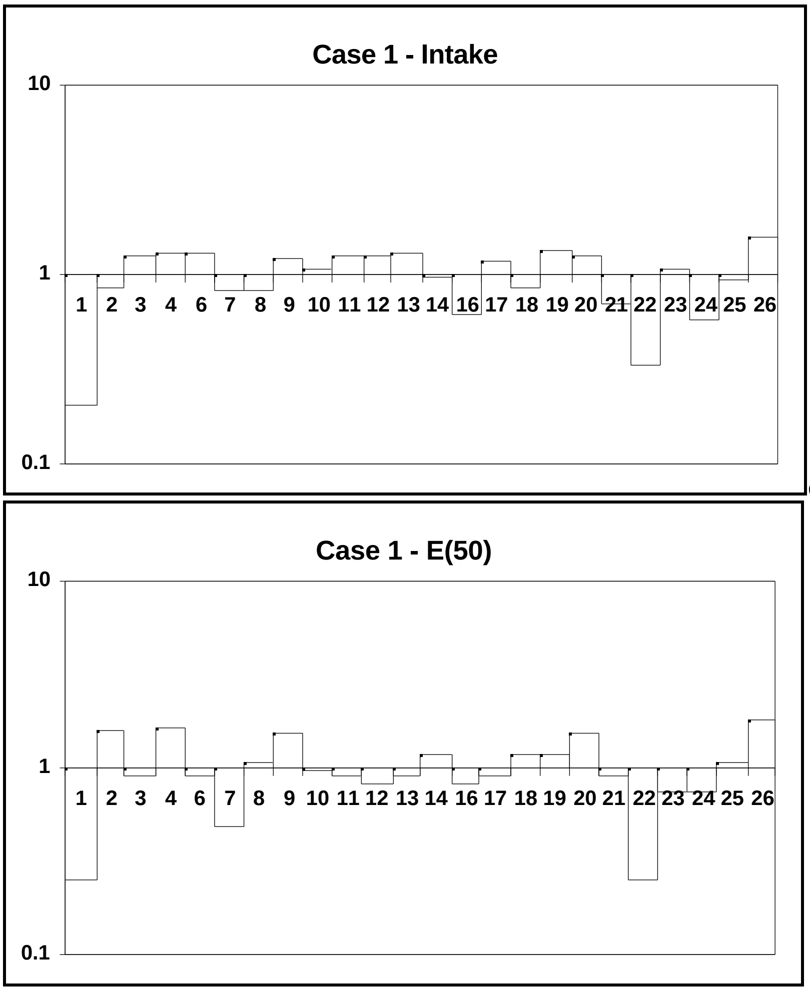

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Fig 3. Illustration of the intercomparison results per participant for Case 1: ^{3}H (HTO), single intake. The results are normalised to the mean value.

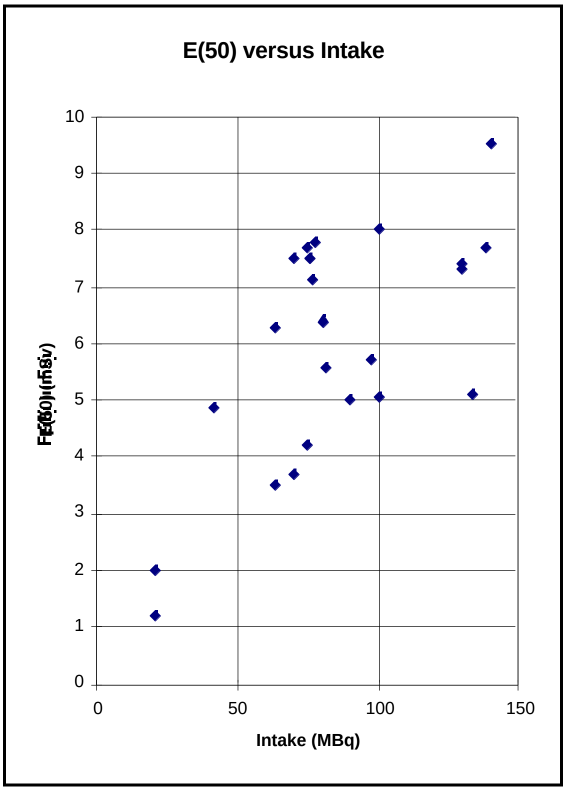

Fig. 4 Relationship between the intake and the committed effective dose for Case 1: ^{3}H (HTO), single intake.

Programme objectives were accomplished in this intercomparison. As a result the IAEA will continue to perform and expand such intercomparisons to cover all other aspects for the assessment of occupational exposure due to intake of radionuclides, namely: direct and indirect methods of monitoring as well as dose calculation. The intercomparison in 2000 will focus on the determination of gamma emitters in urine samples.

Further information

Further information on IAEA radiation protection programmes can be found on the Web site at: www.iaea.org/ns/rasanet/.

Conclusions

The IAEA activities to support internal exposure management through a comprehensive set of Safety Guides, Safety Reports and other documents will soon be completed. The future IAEA activities in this field will focus on training and international intercomparisons. There are many other international and national bodies active in this field, and for the different institutes all over the world responsible for internal exposure management it would be most effective and beneficial if the different efforts would be co-ordinated. The IAEA is open to discussions on any arrangements to facilitate this co-operation.

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