A Structured Approach for the Assessment of Internal Dose: the IDEAS Guidelines

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Running title: IDEAS Guidelines
Abstract:

The need for harmonisation of the procedures for internal dose assessment has been formulated within an EU research project under the 5th Framework Programme. The aim of the project IDEAS (partly funded by the European Commission under contract No. FIKR-CT2001-00160), has been to develop general guidelines for standardizing assessments of intakes and internal doses. The IDEAS project started in October 2001 and ended in June 2005. The project is closely related to some goals of the work of Committee 2 of the ICRP and since 2003 there has been close cooperation between the two groups. The general philosophy of the guidelines is here presented, focusing on the principles of harmonization, accuracy and proportionality. The proposed level of task to structure the approach of internal dose evaluation is also reported. Some details on the internal structure of the guidelines for the different paths of intake are finally provided.
INTRODUCTION

The assessment of internal doses can be divided into two phases, namely (i) determination of the amount of radioactive material in the human body, in body organs or in wounds by direct measurements and/or by indirect methods such as excretion analysis or air monitoring, and (ii) interpretation of the monitoring data in terms of intake and/or internal dose taking into account many influencing factors and assumptions, such as the physical and chemical characteristics of the radioactive substances, the mode of intake, the biokinetic and energy absorption processes, etc. The second phase is particularly important because of the number of variables and uncertainties involved. Although the International Commission on Radiological Protection (ICRP) and International Atomic Energy Agency (IAEA) have published extensive tables of dose per unit intake (dose coefficients), these are default values based on assumptions about the various parameters that may not be valid in specific situations. Determination of the 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, and therefore different numerical solutions will be obtained. This has been demonstrated in various intercomparison exercises [1,2].

The ICRP has recently developed a new generation of more realistic internal dosimetry models, including the Human Respiratory Tract Model (HRTM, ICRP Publication 66 [3]) and recycling systemic models for actinides (ICRP 67 [4] and 69 [5]). These models provide a basis for making realistic predictions of excretion, as well as retention. There are some rough guidelines for individual monitoring recommended by ICRP in Publications 54 and 78 [6]. These guidelines, however, leave many assumptions open, resulting in many different approaches for the interpretation of monitoring data.

This has been illustrated by the 3rd European Intercomparison Exercise on Internal Dose Assessment [2], which considered especially the effects of the new models and the choice of input parameters on the assessment of internal doses from monitoring results. The results in terms of intake and committed effective dose were roughly log-normally distributed with the geometric standard deviation ranging from 1.15 for cases dealing with H-3 and Cs-137, up to 2.4 for cases dealing with Pu-239. A key feature of the exercise was a Workshop, involving most of the participants, at which each case and the approaches taken to assessing it were discussed. Reasons for the differences in the results were identified, including different assumptions about the pattern of intake, and the choice of model. The most important conclusion of the exercise was the need to develop agreed guidelines for internal dose evaluation procedures in order to promote harmonisation of assessments between organisations and countries, which has particular importance in EU countries, because of the mobility of workers between member states.

THE IDEAS PROJECT

The aim of the IDEAS project was to develop guidelines to standardise assessments of internal doses, based on research into the assumptions made, and developed by a group of experts in consultation with potential users. Further information is available at the project website http://www.ideas-workshop.de.

To ensure that the guidelines are applicable to a wide range of practical situations, a database was compiled of cases of internal contamination that include monitoring data suitable for assessment. It contains information on over 200 cases, and more are being added, because it provides a valuable training resource. In parallel, improved algorithms (mathematical methods) for assessing intakes and doses from bioassay data were developed and incorporated in existing software IMIE (Individual Monitoring of the Internal Exposure). A special version of IMIE was developed and distributed to the partners. A version of the IMBA Expert™ program (Integrated Modules for Bioassay Analysis) was also provided for use in the project. About 50 cases from the database were assessed, with at least two independent assessments of many of the cases. The results were collated, and differences in assumptions identified, with their effect on the assessed dose. From the results, and other investigations, draft guidelines were prepared, to provide a systematic procedure for estimating the required parameter values that are not part of the measurement data. A virtual workshop was held on the Internet, open to internal dosimetry professionals, to describe the database and evaluations, and to discuss the draft guidelines, which were revised accordingly. An intercomparison exercise
on internal dose assessment was then conducted, in collaboration with the IAEA, which was also open to all involved in internal dosimetry. Six cases were developed and circulated with a copy of the revised guidelines, which participants were encouraged to follow, to test their applicability and effectiveness. The results were collated and a Workshop held to discuss the results with the participants.

The guidelines have been revised and refined on the basis of the experiences and discussions of the Virtual Workshop. A joint intercomparison exercise was organised together with the IAEA in 2004 in order to test the guidelines and to provide possibilities for the participating laboratories to check the quality of their internal dose assessment methods [11]. This was open to all internal dosimetry professionals. A workshop has been organised early in 2005 together with the IAEA in order to discuss the results of the joint intercomparison exercise together with all interested participants. The final version of the guidelines [12] has been put forward as a basis for national and international guidance.

The guidelines were developed in close collaboration with the ICRP Committee 2 Task Group on Internal Dosimetry (INDOS) [13], which is developing a Guidance Document on internal dose assessment. The draft ICRP Guidance Document is following similar principles, and a similar structured approach to assessments based on the IDEAS Guidelines, but will relate to revised ICRP biokinetic models currently under development by INDOS.

GENERAL PHILOSOPHY OF THE IDEAS GUIDELINES

The overall aims of the Guidelines can be summarised as: harmonisation (by following the Guidelines any two assessors should obtain the same estimate of dose from a given data set), optimisation (the “best” estimate of dose should be obtained from the available data) and proportionality (the effort applied to the evaluation should be proportionate to the dose – the lower the dose, the simpler the process should be).

Harmonisation.

A well-defined procedure is needed and for this reason the process is defined in the Guidelines primarily by means of a series of flow-charts. So far as possible, the guidance has been made widely applicable, i.e., it does not assume that the assessor has the use of sophisticated bioassay interpretation software. The Guidelines are intended to be consistent with ICRP recommendations and guidance. Since they are being developed in a European context, they relate, where appropriate, to the currently recommended ICRP biokinetic and dosimetric models, as applied in ICRP Publications 68 and 78. However, many of the principles and procedures could be applied, or adapted, to other systems. For routine monitoring situations, where typically there is only one measurement relating to each intake, it is reasonably straightforward to define a procedure. However, in special monitoring situations, where typically there is more than one measurement and quite possibly more than one type of measurement (urine, feces…) different options for data handling can easily lead to different evaluated doses, even when the same model, parameter values, and software are used. Another range of options, and opportunities for different evaluated doses, arises in situations where it is appropriate to consider changing parameter values from the ICRP defaults. Proposals are made here for a systematic approach to dose assessment in all these situations.

Optimisation

It is recognised that the uncertainties associated with assessed internal dose can be considerable, especially for actinides which are difficult to detect in the body and have relatively high dose coefficients. Thus if the initial estimate of dose exceeds 1 mSv, it could well be that the possibility of a substantially higher dose (e.g. 6 mSv) cannot easily be excluded. It is then important to make best use of the available information. To do so may well involve changing parameter values from their ICRP default values and guidance is therefore needed on which parameter values might reasonably be varied according to the circumstances.

Proportionality.

The effort applied to the evaluation of incorporation monitoring data should correspond to the level of exposure. On the one hand, if the exposure is likely to be very low with respect to the dose limits, simple evaluation procedures with a relatively high uncertainty may be applied. On the other hand, if the monitoring values indicate the exposure to be close to or even above the dose limits, more sophisticated evaluation procedures have to be applied. These take
LEVELS OF TASK

With respect to operational radiation protection the following “Levels of task” are proposed to structure the approach to the evaluation according to the overall aims.

Level 0

Annual dose (committed effective dose from intakes of radionuclides that occur in the accounting year) <0.1 mSv. No evaluation of dose needed.

Level 1

Simple, “reference” evaluation, with ICRP defaults used for all parameter values, except where there is better a priori information available, e.g. for inhalation intakes information on the particle size distribution (annual dose typically 0.1 – 1 mSv).

Level 2

More sophisticated evaluation using additional information to give more realistic assessment of dose: typically a special assessment of an accidental intake. Comparisons are made of the model predictions (“the fit”) with the data, to choose between alternative parameter values, or to find optimum parameter values (a posteriori). At this Level, the parameters adjusted typically relate to the material (for inhalation intakes the AMAD and absorption Type), and the time of intake if unknown (dose from the intake typically 1 – 6 mSv).

Level 3

More sophisticated evaluation, which applies to cases where there are comprehensive data available, as would be the situation after an accident. The evaluation is an extension of Level 2, typically to parameters relating to the subject (e.g. for inhalation intakes the HRTM particle transport rates). The fundamental approach at this Level is to adjust the model parameter values systematically, in a specific order (“step-by-step” approach), until the goodness of fit is acceptable (i.e. the fits obtained to all the data are not rejected by the specified criteria) (dose from the intake typically > 6 mSv).

STRUCTURED APPROACH TO DOSE ASSESSMENT

The guidelines provide:

- Background information about the biokinetic models and the corresponding bioassay functions for the interpretation of monitoring data.
- Detailed information about the handling and evaluation of monitoring data.
- A structured approach to dose assessment consisting of a step-by-step procedure described in well-defined flowcharts with accompanying explanatory text.

In the following the structured approach is described in more detail. It consists of a series of “Stages”, broadly corresponding to the Levels of task given above. Each Stage consists of a series of “Steps”, and is presented diagrammatically in a flow chart, with a brief explanation of each Step in the text. Detailed descriptions of some aspects of the evaluation process are given in the report.

Stage 1: Level 0 and for higher exposures

Level 0 refers to cases where it is expected that the annual dose (committed effective dose from intakes of radionuclides that occur in the accounting year) is likely to be below 0.1 mSv, even if there were similar intakes in each and every monitoring interval during the year. At this level there is no need to evaluate the intake or dose from the measured values explicitly. The effective dose can be reported as zero, by analogy with the rounding of doses in account of any case-specific information available, so that the uncertainty and bias on the best estimate are as low as reasonable achievable. Thus, the level of task should be related to the expected dose.
Stage 2. Level 1, and for higher exposures: Check on significance of new measurement and consistency with previous evaluations

Level 1 refers to cases where it is expected that the dose from the intake is likely to be above 0.1 mSv. At this level the intake or dose from the measured values should be calculated explicitly (Fig. 2). Before starting the assessment of intake and dose, however, it is recommended to plot the data and to do some simple hand calculations in order to understand the case (Step 2.0). In addition, the statistical significance of the measured value M should be estimated. This includes the assessment of uncertainty on M (Step 2.1) as well as the calculation of the contributions from previous intakes to M (Step 2.2) in order to decide whether M is:

- due to a new intake, or
- due to a previous intake, or
- if it is in contradiction to previous assessments (Steps 2.3 – 2.7).

Stage 3. Standard evaluation procedure at Level 1

Having determined the measured value (M) to be due to a new intake, the intake and dose are evaluated from the net value \( N = M - P \) using \( a \) priori parameter values (Fig. 3). If the dose is assessed to be above 1 mSv, the evaluation should be repeated according to Stage 4, in which the parameter values chosen \( a \) priori may be adjusted, if necessary to obtain an acceptable fit to the data. The standard evaluation procedure should be applied only for routine monitoring. Case or site specific parameter values should be assigned as far as they are available.

Stage 4. Identification of pathway of intake for special evaluation above Level 1

Special procedures are needed for the evaluation when there is evidence for a committed effective dose of more than 1 mSv or in all cases of special monitoring. In all these cases the evaluation procedures depend to some extent on the pathway of intake. Thus, in Stage 4 the pathway of intake has to be identified.

Stage 5. Special procedure for inhalation cases above Level 1

The special procedure is grouped in three subsequent stages (Fig. 4). In the first stage (5A), a simple evaluation is carried out using parameter values chosen \( a \) priori: before the evaluation is carried out. The procedure is very similar to the “Standard procedure” (Stage 3). The main difference is that in a special procedure there should be more than one measurement. In the second stage (5B), procedures are applied for varying the two main factors related to the inhaled material: the AMAD and absorption Type, and also the time of intake, if not known, using the measurement data (\( a \) posteriori). In the third stage (5C), an advanced evaluation is carried out. It applies to cases where there are comprehensive data available. The fundamental approach of this stage is that the model parameter values are adjusted systematically, in a specific order, until the goodness of fit is acceptable (i.e. the fits obtained to all the data are not rejected by the specified criteria).

Similar procedures have been defined for ingestion cases (Stage 6) and for mixed inhalation and ingestion cases (Stage 7). For more information see the report on the guidelines [12].

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Acknowledgements

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Figures:

Stage 1

1.1 Identify monitoring value M

1.2 M < Mc

   yes

   1.2.1 Level 0:
          No evaluation needed

   no

1.3 Above Level 0:
          Evaluation needed

Stage 2

End

Fig. 1: Stage 1. Check of need for evaluation
Stage 2

2.0 Understanding the case

2.1 Assessment of uncertainty on measured value M (or application of default uncertainty)

2.2 Calculation of contributions from previous intakes (P)

2.3 \( M > SF \cdot P \)

2.3.1 There is a new significant intake; calculation of net measured value \( N = M - P \)

2.4 \( P/SF < M < P \cdot SF \)

2.4.1 There is no new significant intake (confirmation of previous assessments)

2.5 There is a discrepancy with previous evaluations

2.6 Value is reliable

2.6.1 Special evaluation of previous intakes needed

2.7 Check measured value or repeat measurement

Stage 3

Stage 4

End

Fig. 2: Stage 2. Check on significance of new measurement and consistency with previous evaluations
Fig. 3: Stage 3. Standard evaluation procedure at Level 1
Fig. 4: Stage 5. Special procedure for inhalation cases above Level 1 – Overview