

A new approach for harmonisation of internal dosimetry: The IDEAS Guidelines

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Abstract. The need for harmonization of the procedures for internal dose assessment has been formulated within an EU research project under the 5th Framework Program. 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. To ensure that the guidelines are applicable to a wide range of practical situations, drafts have been discussed with dosimetry professionals from around the world by means of a virtual workshop on the Internet, early in 2004, via the IDEAS web site. The guidelines have been refined on the basis of the experiences and discussions of a workshop celebrated at the IAEA headquarters in April 2005 after a joint IDEAS/IAEA Intercomparison Exercise on Internal Dose Assessment aimed at testing the application of the guidelines. The work of refinement of IDEAS guidelines was continued in the frame of the CONRAD Project, partially funded by the European Commission under the auspices of the Euratom 6th Framework Program for research and training in nuclear energy, Contract No FI6R-012684. The general philosophy of the guidelines is here presented, focusing on the principles of harmonization (any assessors should obtain the same estimate of dose from a given data set); accuracy (the “best” estimate of dose should be obtained from the available data) and proportionality (the effort applied to the evaluation should be proportionate to the dose – the lower the dose, the simpler the process should be). The proposed level of task to structure the approach of internal dose evaluation is also reported. Finally some information about the dissemination of the IDEAS Guidelines and supporting software is provided.

KEYWORDS: *IDEAS Guidelines, internal dosimetry, incorporation monitoring, intercomparison exercises*

1. Introduction

The interpretation of the incorporation monitoring data is influenced by many 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 International Commission on Radiological Protection (ICRP) and the International Atomic Energy Agency (IAEA) have published extensive

tables of biokinetic functions and dose per unit intake (dose coefficients). However, 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. The ICRP has developed a new generation of more realistic internal dosimetry models, including the Human Respiratory Tract Model (HRTM, ICRP Publication 66 [1]) and recycling systemic models for actinides (ICRP 67 [2] and 69 [3]). 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 Publication 78 [4]. These guidelines, however, leave many assumptions open, resulting in many different approaches for the interpretation of monitoring data. So, 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 [5,6].

The 3rd European Intercomparison Exercise on Internal Dose Assessment [6] 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. This was the reason to initiate the IDEAS project.

2. 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. 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 [7]. It contained by the end of the project information on over 200 cases, and more have been added by now, 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) [8,9]. A special version of IMIE was developed and distributed to the partners. A version of the IMBA Expert™ program (Integrated Modules for Bioassay Analysis) [10,11] 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 (www.ideas-workshop.de), open to internal dosimetry professionals, to describe the database and evaluations, and to discuss the draft guidelines, which were revised accordingly.

The guidelines have been revised and refined on the basis of the experiences and discussions of the Virtual Workshop. A joint intercomparison exercise on internal dose assessment was then organised and conducted in collaboration 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 [12,13]. This was open to all internal dosimetry professionals. 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 was organised early in 2005 with the IAEA to discuss the results of the exercise with all interested participants. The final version of the guidelines [14] has been put forward as a basis for national and international guidance.

3. The IDEAS Guidelines

3.1 General philosophy

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), accuracy (the “best” estimate of dose should be obtained from the available data) and proportionality (the effort applied to the evaluation should be proportionate to the dose – 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, faeces...) 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.

Accuracy

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 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.

3.2 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 (dose from the intake typically 0.1 – 1 mSv).

Level 2

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).

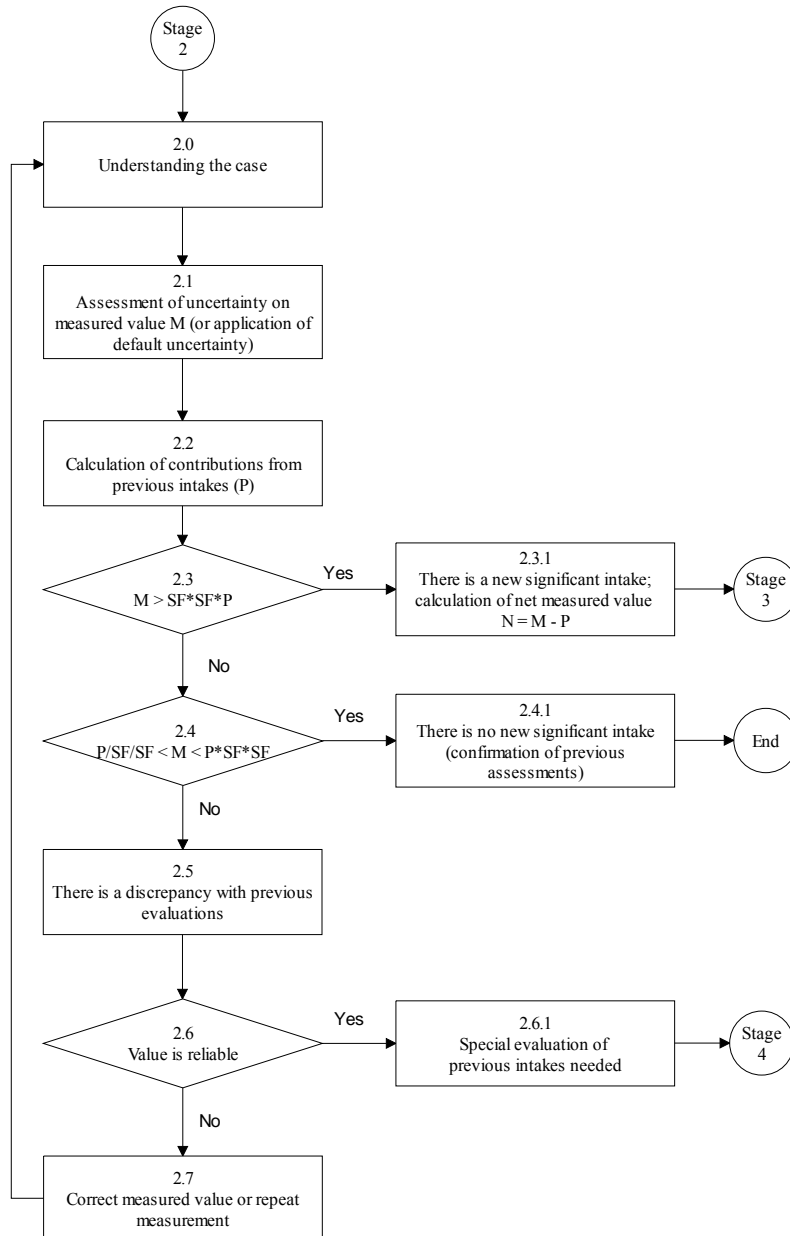
Level 3

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).

3.3 Structured approach to dose assessment

The guidelines provide a structured approach to dose assessment consisting 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 flowchart, with a brief explanation of each Step in the text. Detailed descriptions of all aspects of the process are given in the report [14]. In this paper the structured approach is illustrated by the example of Stage 2 (check on significance of new measurement and consistency with previous evaluations, Fig 1). Before starting the assessment of intake and dose 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 (Step 2.3.1), due to a previous intake (Step 2.4.1), or if it is inconsistent with previous assessments (Step 2.5). In case of inconsistency there are the options (i) the measured value is reliable (Step 2.6), then the evaluation of the previous intakes is wrong and has to be repeated including the new measurement (Step 2.6.1) or (ii) the measured value is wrong and has to be deleted or corrected (Step 2.7). The key parameter for all these decisions is the scattering factor, SF which has been defined for describing the uncertainty of the measured values including the error due to counting statistics (Type A error) and the error due to calibration, sampling, recovery etc. (Type B error). For more information see the report on the guidelines [14].

Figure 1: Stage 2. Check on significance of new measurement and consistency with previous evaluations



3.4 Test of the IDEAS Guidelines

For testing of the IDEAS Guidelines a new intercomparison exercise for the assessment of doses from intakes of radionuclides was organised jointly by the International Atomic Energy Agency (IAEA) and the IDEAS project [12]. Full details are available in a report [13] on the Internet. Six cases were selected to cover a wide range of practices in the nuclear fuel cycle and medical applications. These cases were: (1) acute intake of HTO, (2) acute inhalation of the fission products ^{137}Cs and ^{90}Sr , (3) acute inhalation of ^{60}Co , (4) repeated intakes of ^{131}I , (5) intake of enriched uranium and (6) single intake of Pu isotopes and ^{241}Am . Four of the cases (1, 2, 5 and 6) are real, and all except case 5 have been published. Cases 3 and 4 were artificially constructed.

Because of the easy access to the cases via the Internet, and the worldwide promotion of the intercomparison exercise by the IDEAS group and the IAEA, there was a large number of participants

from all over the world. Participants were free to undertake only those cases relevant to their work. Of the 74 participants who assessed at least one case, 36% provided an answer to all six cases. The highest participation (84%) was for the cobalt and iodine cases and the lowest (57%) was for the americium part of case 6. The statistical procedure used in the previous exercise [6] was applied to identify outliers in each set of results. Table 1 summarises results (committed effective doses, E(50)) excluding outliers. The results were discussed with the participants during a workshop held by the Agency in April 2005. Based on these discussions, the IDEAS Guidelines were finalised and were presented 2006 at the Workshop on Internal Dosimetry of Radionuclides in Montpellier, France [15].

Table 1: Statistical evaluations of the E(50) results of the IDEAS/IAEA intercomparison exercise [12,13] (excluding outliers)

Case number	Radionuclide	Geometric mean (mSv)	Geometric standard dev.	Number of results ^(a)
1	³ H	26	1.06	46 (12)
2	¹³⁷ Cs	0.66	1.16	52 (6)
	⁹⁰ Sr	7.2	1.94	48 (10)
3	⁶⁰ Co	5.0	1.4	56 (6)
4	¹³¹ I	2.6	1.07	50 (13)
5	²³⁴ U	27	2.4	38 (3)
6	²⁴¹ Am	52	2.1	32 (3)
	²³⁹ Pu	140	1.58	31 (5)

^(a) number of outliers in brackets

This intercomparison exercise showed that the IDEAS Guidelines could have a positive influence on the harmonisation of reported intakes and doses. Considering the limited time provided for the solution of the cases (2 months), the need to be acquainted with the Guidelines and their use, the number of participants that have correctly applied the Guidelines is encouraging. An important finding was the lower occurrence of outlying values among those who applied the Guidelines than among those who did not. However, even very detailed guidelines cannot help if unrealistic assumptions or simple mistakes are made. There is still a need for adequate training, experience and quality control.

Some 20% of participants used the IDEAS Guidelines correctly and reached results that can be considered accurate. In view of this, more effort will be put into the promotion and correct application of such guidelines in the international internal dosimetry community, together with dedicated training. It is considered that their greatest effect will be on new professionals in the field. The individual results of the participants should also help their laboratories to demonstrate (e.g. to customers and regulators) their effectiveness in assessing occupational doses to individuals from intakes of radionuclides. It is important that participation in such exercises is available on a regular basis in future.

4. Follow-up projects

The IDEAS Guidelines have been refined in the framework of the project, 'A Coordinated Network for Radiation Dosimetry' (CONRAD) [16,17,18]. This project started in April 2005 and ended in February 2008 and was funded within the EURATOM 6th Framework Programme for research and training in nuclear energy (contract no. FI6R-012684). Work Package 5 of the CONRAD project was dedicated to the coordination of research on internal dosimetry. This work package was sub-divided into five task groups and the work of Task Groups 5.1 and 5.5 were related to the refinement of the IDEAS Guidelines and the update of the IDEAS Databases, respectively. A new webpage, <http://www.bologna.enea.it/attivita/ideas.html>, has been developed as an internal dosimetry site, providing details of the status of the IDEAS guidelines and the work related to tasks 5.1 and 5.5 of the CONRAD project.

4.1 Refinement of the IDEAS Guidelines

The refinement of the IDEAS Guidelines was related mainly to (i) the scattering factors, (ii) the number and type of data required for dose assessment and (iii) the evaluation of the effective AMAD. Scattering factor values have been calculated for different radionuclides and types of monitoring data using real data contained in the IDEAS Internal Contamination Database. Preliminary results are broadly in agreement with the values suggested in the IDEAS Guidelines. However, the scattering factor values for faecal excretion (1.9 – 3.5) are at the lower end of the range (2 – 5) suggested by the IDEAS Guidelines [19]. In future, further analysis should be carried out, particularly for those elements and routes of intake for which the log-normal test on the pool of data from different subjects fails. For more details concerning the refinement of the IDEAS Guidelines see website <http://www.bologna.enea.it/attivita/ideas.html>.

Recently, the NCRP has developed a biokinetic model for radionuclide contaminated wounds [20]. So it was also discussed to include the wound pathway into the IDEAS Guidelines. In the NCRP model, wound retention is described by five compartments and the material is removed from the wound site by transport into blood directly or via the regional lymph nodes. The model defines seven default wound retention categories relating to the chemical and physical properties of the material. There are four categories for soluble material (weak, moderate, strong and avid) and categories for particles, fragments and colloids. The particle category contains material, typically relatively insoluble, whose individual sizes are ≤ 20 nm, whereas the fragment category includes larger particles and fragments whose size and/or quantity of material are sufficient to cause a foreign body tissue reaction. The colloid category consists of radionuclides that exist as frank colloidal material prior to deposition, and typically have small fractions of the deposited amount that clear rapidly from the wound site.

Before including the wound pathway into the IDEAS Guidelines, it is necessary to gain some experience in assessing wound cases. So it was agreed to use the NCRP wound model to evaluate some plutonium wound cases contained in the IDEAS Internal Contamination Database [7]. Six cases where no decorporation therapy was used were considered. For each case, the urine data were used to evaluate the intake assuming a scattering factor value of 1.7 [19]. The daily urinary excretion functions per unit activity of plutonium deposited in the wound have been provided by Ishigure [21] for each of the default retention categories. Ishigure derived these functions by implementing the NCRP wound model and the ICRP Publication 67 systemic biokinetic model for plutonium [2]. These functions were used in the assessment of these cases. Good fits to the urine data have been obtained for four cases. However, it was not possible to obtain a good fit with default wound retention categories for the two other cases. Here further investigation is required. One suggestion to solve the problem is to assume a mixture of two default retention categories, either inside the ‘soluble category’ (weak, moderate, strong and avid) or inside the ‘insoluble category’ (colloid, particles or fragment). Another option would be to vary model parameter values. However, which parameters should be varied and to what extent are questions that need to be answered before implementing the wound pathway into the IDEAS Guidelines.

4.2 Further development of the IDEAS Databases

During the IDEAS project, three databases: the Bibliographic Database, the Internal Contamination Database and the Evaluation Database have been developed. The Bibliographic Database is a compilation of publications from the literature, which contain information on cases of internal contamination from which intake and committed doses could be assessed. During the CONRAD project, new references have been added to the database, some references have been corrected and repeated references have been removed. The Internal Contamination Database [7,22] contains cases of internal contamination compiled from references of the previous database. For each case, the case description and the monitoring results are given. During the CONRAD project, new cases have been added to the database, so it now contains 255 cases. Also available is the Evaluation Database. In Work Package 3 of the IDEAS project [23], evaluations provided by the contractors were collated in an Evaluation of Cases Database. All these databases are available for download at

<http://www.sckcen.be/ideas/>. New contamination cases are highly welcome (contact Hurtgen: churtgen@sckcen.be).

5. Dissemination of the IDEAS Guidelines

5.1 IAEA

The International Atomic Energy Agency (IAEA) organizes in cooperation with the Government of the Czech Republic, EURADOS Working Group 7 Internal Dosimetry and the Czech Technical University in Prague a Regional Training Course on Advanced Methods for Internal Dose Assessment entitled *Application of IDEAS Guidelines and dissemination of CONRAD internal dosimetry results*. The course will be held on 2-6 February 2009 in Prague, Czech Republic. The purpose of the course is to provide the participants with advanced methodologies for internal dose assessment and practical skills to implement the IDEAS Guidelines in the field of monitoring of intake of radionuclides and to provide training in principal concepts and methods used for internal dose assessment of exposure due to intakes of radionuclides, with information on CONRAD Internal dosimetry results. It is anticipated to hold more such courses in future for further dissemination of the IDEAS Guidelines.

5.2 ICRP

The guidelines were developed in close collaboration with the ICRP Committee 2 Task Group on Internal Dosimetry (INDOS) [25], which is developing a Guidance Document on internal dose assessment. The draft ICRP Guidance Document (GD) 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. The information provided in the GD will be a significant development from that given in publications 54 and 78 on the interpretation of bioassay measurement data. The draft GD has been published on the ICRP web site in 2006 and many comments were received following the publication. The comments were used to refine the draft GD and the IDEAS Guidelines as well. In 2007, however, it was decided to cancel the development of the GD and to include only some essentials of the GD into the OIR series.

5.3 ISO

The disillusioning experience with the past intercomparison exercises was also recognised by the International Standardization Organization (ISO). Because of the substantial differences between national regulations, concepts, and dose assessment procedures the ISO recently initiated projects to standardize the monitoring of workers, the requirements for measuring laboratories and the processes for the quantitative evaluation of monitoring data [26]. The anticipated standards include the need for a monitoring programme and the design of a monitoring programme, i.e. the methods and intervals, decision levels and approaches for dose assessments. These approaches correspond widely to the IDEAS Guidelines. There is a similar level of task structure with the same decision levels and evaluation procedures, this being of great importance for the harmonisation of internal dosimetry worldwide.

6. Supporting software

There are several commercial computer codes for the evaluation of incorporation monitoring data, such as IMBA ExpertTM [8,9], IMIE [10,11] or IDEA System [24]. IDEA System has been developed in the Karlsruhe Research Centre especially for assisting dosimetrists in applying the IDEAS Guidelines and other relevant recommendations for incorporation monitoring and internal dosimetry. IDEA System (Internal Dose Equivalent Assessment System) gives guidance to the user with respect to (i) planning of monitoring (estimation of potential exposures, decision on the requirements of monitoring, definition of optimum measuring techniques and monitoring intervals), (ii) performing routine and special monitoring, and (iii) evaluation of primary monitoring results. According to the

IDEAS Guidelines the overall aims of the software can be summarized as: harmonization, accuracy and proportionality. The harmonization covers (i) the decision on the requirement of incorporation monitoring, (ii) the methods applied for incorporation monitoring and (iii) the methods applied for the evaluation of incorporation monitoring results. IDEA System provides well-defined procedures for all these three topics, which are consistent with the IDEAS Guidelines. The software is intended to be a dynamic tool for incorporation monitoring and for interpretation of monitoring data according to the overall aims mentioned above. So the software is continuously extended and adjusted taking into account the progress of monitoring techniques, the development of biokinetic models and the special needs and requirements of the users. The software provides the following features for evaluation of monitoring data:

- Standard evaluation (Level 1 of IDEAS Guidelines) with default parameters (single inhalation in the middle of monitoring interval; default absorption type and AMAD); automatic correction for contributions from previous intakes; automatic check of consistency with previous evaluations
- Standard evaluation (Level 2 of IDEAS Guidelines) with case or site specific parameters for single or chronic intakes by inhalation, ingestion or injection; automatic correction for contributions from previous intakes; automatic check of consistency with previous evaluations
- Special evaluation (Level 2 or 3 of IDEAS Guidelines) with individual adjustment of model parameter values (fitting of time of intake, absorption type, particle size, or f_1 -value)
- Special evaluation using direct internal dosimetry (integration procedure; calculation of cumulated activity for H-3 in urine, Iodine isotopes in the thyroid or Cesium isotopes in the whole body)

IDEA System can be applied for all evaluation stages according to the IDEAS Guidelines except the “high end” stages 5c, 6c and 7c, where the biokinetic models have to be modified. For these stages other software such IMBA ExpertTM [8,9] or IMIE [10,11] may be used. However, IDEA System provides also many other tools for internal dosimetry, such as the assessment of the effective dose to the offspring due to intakes of the mother. For more information see the website www.idea-system.com.

Acknowledgements

The IDEAS project was partly funded by the European Commission under contract No. FIKR-CT2001-00160. In addition, the IDEAS/IAEA intercomparison exercise was partly funded by the IAEA.

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