EURADOS Report 2019-01
Neuherberg, April 2019

InterComparison on Internal DOSE Assessment – ICIDOSE 2017
Analysing the intercomparison results

C.M. Castellani, A. Andrasi, A. Giussani,
T. Pázmándi, G. Roberts, G. Etherington

ISSN 2226-8057
ISBN 978-3-943701-18-0

European Radiation Dosimetry Group e. V.

EURADOS Report 2019-01

Neuherberg, April 2019

InterComparison on Internal DOSE Assessment – ICIDOSE 2017
Analysing the intercomparison results

Authors: C.M. Castellani[1], A. Andrasi[2], A. Giussani[3], T. Pázmándi[2], G. Roberts[4], G. Etherington[5]

[1] ENEA, Italy

[2] MTA EK, Hungary

[3] BfS, Germany

[4] Nuvia Limited, UK

[5] PHE, UK retired

ISSN 2226-8057

ISBN 978-3-943701-18-0

Imprint

Issued by:
European Radiation Dosimetry e.V.
Postfach 1129
D-85758 Neuherberg
Germany
office@eurados.org
www.eurados.org

The European Radiation Dosimetry e.V. is a non-profit organization promoting research and development and European cooperation in the field of the dosimetry of ionizing radiation. It is registered in the Register of Associations (Amtsgericht Braunschweig, registry number VR 200387) and certified to be of non-profit character (Finanzamt Braunschweig-Altewiekring, notification from 2008-03-03).

Liability Disclaimer

No liability will be undertaken for completeness, editorial or technical mistakes, omissions as well as for correctness of the contents.

Content:

Abstract

Internal dose assessment often requires complex processes and judgements. "Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides" (TECHREC) was developed during 2014 to 2016 as a tool for internal dosimetrists. The TECHREC recommendations have been published in the Radiation Protection document series of the European Commission as document RP188 (EC 2018). They aim to encourage harmonisation, to present a complete account of the principles of individual monitoring and internal dosimetry, and to provide comprehensive guidance and recommendations on best practice.

To check the practical applicability of the TECHREC Recommendations an internal dose inter-comparison exercise, titled *ICIDOSE 2017*, was promoted in mid-2017 by the Working Group 7 "Internal dosimetry". Four case studies with different degrees of complexity were proposed: ^{60}Co: simple special monitoring; ^{125}I: simple routine monitoring; $^{234+235+238}$U: complex confirmatory and special monitoring; ^{241}Am: very complex special monitoring after an accident.

The evaluation period of the inter-comparison was from September 2017 to mid-December 2017.

Results were received from 66 participants from 26 countries.

Preliminary analyses of the submitted results were presented during an EURADOS WG7 meeting in Lisbon, Portugal (Feb. 2018), at the 5th European IRPA Congress (The Hague, The Netherlands, 4-8 June 2018) (Pázmándi 2018a), at the HEIR 2018 Conference (Fontenay-aux-Roses, France, 8-11 October 2018) (Giussani 2018) as well as in a Note to Radiation Protection Dosimetry (Castellani 2018).

A participants' workshop was held at the Federal Office for Radiation Protection (BfS) in Munich on 18 and 19 October 2018.

This report presents the detailed description of the intercomparison exercise, namely:

- General and case specific objectives of the action
- Study coordination and design
- Chronology of actions
- For each case :
  - Case description provided to participants
  - Overall statistics of the results in terms of intake and committed effective dose
  - Observations and discussion on selected aspects
  - Errors performed by participants during the assessment - either reporting errors or method errors
- Discussion themes at the participants' workshop
- Overal summary conclusions of the action
- Perspectives for the harmonization of internal dose assessment after the transposition of EURATOM Directive 59/2013 (EC 2014) inside Member States' regulations.

Four annexes are included:

- Annexe 1 : the list of participants.
- Annexe 2: the reduced tabulation of the results provided by participants (full access to electronic data will be available to participants separately from this report);
- Annexe 3: explanation of applied robust statistics;
- Annexe 4: the presentations of the participants' solutions to the workshop

1. Introduction

The estimation of occupational intakes of radionuclides and the resulting committed effective dose requires the acquisition, processing and interpretation of relevant measurement data. This often involves complex processes and judgements such as, for instance: the selection and application of appropriate biokinetic models and parameters; the identification of relevant measurement data and estimation of the uncertainties within that data; the use of default assumptions and the extent to which the assessment should be adapted to case-specific circumstances. This situation can lead to a wide scope for subjectivity within the assessment process, to the extent that often a single data set can produce divergent estimates of intake and dose if interpreted by different assessors (IAEA 1999) (IAEA 2007). In recent years there have been various published Standards and References (Doerfel 2006), (ISO 2011), (Castellani 2013) which have sought to promote consistency in various aspects of internal dosimetry monitoring, measurement and assessment. However, no single document was available with a complete account of the subject, although such a document does exist for the case of external exposures: in 2009, the European Commission published "Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation" (EC 2009), with the aim to provide comprehensive, detailed, authoritative and internally consistent recommendations and to encourage harmonisation and the eventual mutual recognition of services.

In June 2013 the European Commission issued a tender for the development of a complementary document for internal dosimetry. The task for delivering this project was awarded to EURADOS Working Group 7 (WG7) in the form of a service contract with the European Commission Directorate-General for Energy (DG-ENER). A dedicated Task Group within WG7 developed comprehensive documented guidance "Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides" (abbreviated as TECHREC) covering all of the main technical aspects associated with occupational internal dosimetry. The development of this document considered the requirements of EU Council Directives, existing relevant technical references, and the input from internationally recognised experts in the field of internal dosimetry. This project was completed in a 2-year period (May 2014 - May 2016).

The report was published in the Radiation Protection Series of the European Commission on 10 September 2018 as publication Radiation Protection 188 (EC 2018), and will be further on referred to as RP188 in this report.

Agreement on the use of RP188 for the purpose of this exercise, prior to its official publication, was obtained from the European Commission before launching the Intercomparison exercise ICIDOSE 2017 (17/5/2017).

1.1 The RP188 Recommendations (TECHREC)

RP188 is an extensive and substantial document which provides technical recommendations for monitoring individuals for occupational intakes of radionuclides. It aims to provide guidance on those aspects of the implementation of the Directives of the European Union (EU) Parliament and of the Council Directives of the EU that are directly related to individual monitoring of internal exposures, and to encourage harmonisation and the eventual mutual recognition of services. It

presents a complete account of the principles of individual monitoring and internal dosimetry, and provides comprehensive guidance and recommendations on best practice.

A comprehensive set of recommendations is provided on: (i) roles and duties of dosimetry services; (ii) monitoring programmes; (iii) monitoring methods; (iv) assessment of internal doses from monitoring measurements; (v) accuracy requirements and uncertainty analysis; (vi) quality assurance, and criteria for approval and accreditation; and (vii) radon measurement and dosimetry for workers. The recommendations are presented in the form of answers to specific, practical questions which are listed at the beginning of each chapter. Annexes provide supporting information on biokinetic and dosimetric models, monitoring and dosimetry for first responders after a major accident, and the application of internal dosimetry to assessments of risks to health. One Annex provides a set of examples that demonstrate key features of the technical recommendations. The final Annex presents the full set of recommendations.

The target audience of the document encompasses internal dosimetry services, competent authorities, radiation protection experts, site operators responsible for radiation protection programmes, laboratories providing bioassay services and government bodies aiming to harmonise regulations and guidance.

The main source documents used in developing the Technical Recommendations are shown in Figure 1-1: the arrows indicate the flow of information; solid arrows indicate the primary sources; grey-shaded rectangles represent documents which were subject to revision at the time of development of the Recommendations. It is also noted that since the development of these Recommendations IAEA has published the General Safety Guide GSG-7 "Occupational Radiation Protection" (IAEA, Vienna, 2018).

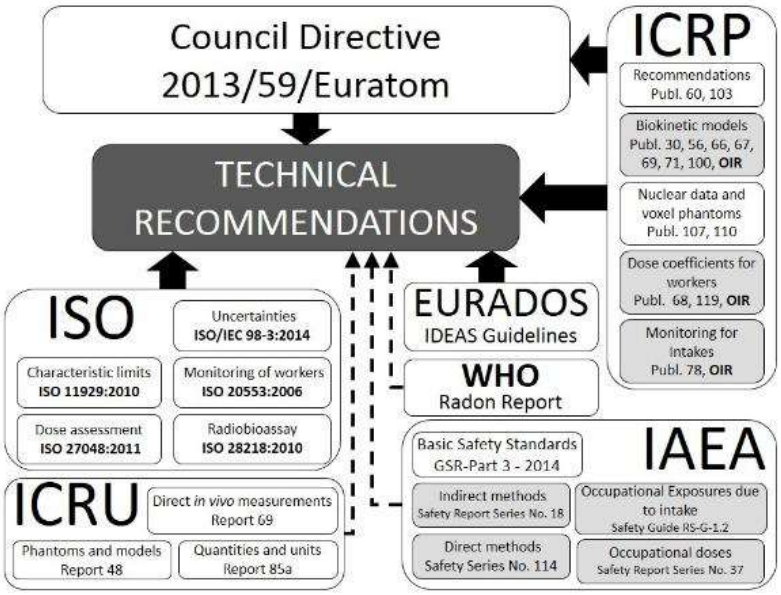


Figure 1-1 : Main sources of information of RP188 Recommendations

The aims of the Technical Recommendations are:

- encourage the harmonisation of methodologies for the assessment of intakes of radionuclides used by internal dosimetry services in the EU;
- provide the basis for uniform approval criteria for internal dosimetry services;
- standardise the criteria for the mutual recognition of dose records.

1.2 The OIR Report Series

Reference dose coefficients and bioassay functions for occupational exposures are published by ICRP in its Publication 68 and 78 (ICRP 1994b) (ICRP 1997).

With Publication 103 (ICRP 2007), ICRP introduced a new way to assess effective dose and also modified some reference values used for its estimation. Specifically:

- The values of the radiation weighting factors wR and of the tissue weighting factors wT have been updated;
- A new composition of the "remainder" target region has been suggested, which is different between Reference Male and Reference Female;
- The methodology for calculating dose for the "remainder" has been simplified, consisting now of a simple averaging of the equivalent doses for those organs and tissues belonging to the “remainder”;
- A new equation for calculating effective dose has been introduced based on the separate calculation of sex-specific equivalent doses to the organs of the Reference Male and of the Reference Female, and sex-averaging.

In addition to that, new Computational Reference Phantoms for Monte Carlo radiation transport calculations (ICRP 2009) and a new model of the Human Alimentary Tract (HATM, (ICRP 2006)) have been published by ICRP.

All these recent changes are implemented in the Occupational Intakes of Radionuclides (OIR) series of publications (ICRP 2015, 2016, 2017) that replace the Publication 30 series and Publications 54 (ICRP 1988) , 68 (ICRP 1994b), and 78 (ICRP 1997). The issue of the OIR series of Publications has provided the opportunity to conduct an update of the ICRP 66 respiratory tract model (HMRT, (ICRP 1994a) and of the systemic models describing distribution and retention of radionuclides which have been absorbed in the systemic circulation. Part 1 of the OIR series of Publications describes the general aspects of assessment of internal occupational exposure to radionuclides, including methods of individual and workplace monitoring, and the biokinetic and dosimetric models used. The subsequent publications Parts 2-4 (ICRP 2015, 2016a, 2016b, 2017) provide data on individual elements and their radioisotopes, including dose coefficients (dose per activity content) and bioassay functions (activity per intake vs. time of incorporation) for all absorption types and for the most common isotope(s) of each element. A comprehensive set of dose coefficients and bioassay functions is contained in the electronic annex that accompanies the OIR series of reports (ICRP 2018).

2. Description of the intercomparison exercise

2.1 Objectives

The primary objective of this study is to assess how effective the RP188 document is when applied in practice. This was determined by the preparation of four different case studies which were distributed to participants. The participants were requested to apply RP188 to make estimates of total intake (Bq) and total committed effective dose (mSv) for each case. Each case also included secondary objectives representing realistic technical challenges that might be encountered in practice. Full details are described in Section 2.5.

2.2 Study coordination and design

The intercomparison was performed by a Core Group of five members of EURADOS WG7: Carlo-Maria Castellani coordinator and responsible for Case 2, Andor Andrasi responsible of Case 4, Augusto Giussani responsible for Case 1 and on-site organizer of the workshop in BfS, Neuherberg, Gareth Roberts responsible for Case 3 and Tamás Pázmándi (TP) responsible of the collection of data and setting up of the results database. This Core Group was tasked with the preparation and distribution of the case studies; receipt and processing of responses from recipients; analysis of the submitted results; preparation of 'ICIDOSE Reference (or Recommended) Solutions' - these being the values of the results that are determined by following the methodology described in the RP188 document for each case; organisation of a participants' workshop; preparation of reports.

The study was designed by selecting three real-life cases and creating one artificially generated hypothetical case. The cases were selected on the basis that they would each represent a realistic challenge that might be encountered in practice, and also to represent a range of different radionuclides and exposure scenarios.

Standardised case-files were created in Excel spreadsheets to provide information to the participants on:

- The primary and secondary objectives for each case;
- A description of what information was known of the exposure incident;
- Anonymised personal data of the exposed person;
- Personal in-vivo and/or in-vitro measurement data;
- Detailed instructions as to what information was required from the participant;
- Deadline and address for return of responses.

In addition, standardised interactive PDF forms were created for participants to use to return their responses. This enabled data capture and processing to be conducted more efficiently, and reduced the risks of transcription errors.

The intercomparison action was publicised via the normal communications channels as used by EURADOS, and organisations were invited to register their interest. This invitation was open to any relevant organisation globally, and was not limited to just European organisations.

The anonymity of each participant to the intercomparison action has been preserved in each stage of the submission and evaluation of results. The correspondence between personal identification code (PID) and name is known only to the relevant participant and to the members of the Core Group.

A participant can use the present report and the PID (formally assigned by individual letter from the Coordinator of the inter-comparison) if required to identify their performance for accreditation or approval purposes to demonstrate the degree of quality of their assessed results.

2.3 General presentation of the cases

A detailed presentation of the materials provided to participants for each Case is presented in the first paragraph of each relevant chapter (Chapters 5, 6, 7 and 8).

Some of the principal characteristics of each case are summarised below.

2.3.1 Case 1: ^{60}Co

The first case features a hypothetical acute exposure to an airborne release of ^{60}Co aerosol. Whole Body Monitoring and urine sampling data were generated artificially using the latest ICRP reference models and data as published in Part 2 of the report series on Occupational Intakes of Radionuclides (ICRP 2016a), modified by randomized realistic uncertainties. This case had to be evaluated both with the reference models and data of the ICRP Publication 60 series (ICRP 68/78/119)[1] (ICRP 1991, 1997, 2012) and those of the new reports on Occupational Intakes of Radionuclides (OIR Report Series, ICRP Publications 130/134/137) (ICRP 2015, 2016a, 2017). As the OIR publication was not yet available at the time of the exercise, relevant data were provided to the participants with kind permission of ICRP Committee 2, and specifically of the ICRP Task Group on Internal Dose Coefficients.

2.3.2 Case 2: ^{125}I

The second case was an actual instance of exposure to ^{125}I vapour, featuring multiple exposures over a thirteen months period. Work had been performed in hermetically sealed boxes and chambers incorporating ^{125}I. However, leakages of small quantities of ^{125}I into the air of the working areas was practically unavoidable due to the high volatility of this radionuclide at all stages of production. Due to work procedures and the potential for exposure, routine thyroid monitoring was established with a monitoring interval of approximately 90 d.

The beginning of the exposure period was 22/02/1986. An unexpected exposure was detected by the second monitoring result, therefore two further special thyroid measurements were requested and performed on 2/9/1986 and 30/9/1986. Routine monitoring then continued, with measurements on 4/12/1986 and 28/3/1987. The reported thyroid monitoring data were considered as being collected in a sequential mode; therefore, an iterative dose assessment procedure for each exposure period had to be applied considering, when available, the subsequent special thyroid measurements results in the same monitoring period.

The end of the monitoring period for transfer to another type of work was 1/4/1987.

1 For the sake of simplicity, in the rest of the document the analysis using reference data and definitions from the ICRP Publication 60 series will be referred to as "analysis according to ICRP 78".

2.3.3 Case 3 : $^{234}U+^{235}U+^{238}U$

The third case was adapted from a real event: a confirmatory monitoring programme for U isotopes in an exposed worker indicated a result greater than the Investigation Level, which led to the establishment of a special monitoring programme. The dose had to be evaluated without knowing the grade of enrichment (natural, enhanced, depleted) of the aerosol being inhaled.

The nature of the operations in the facility included decontamination of contaminated components, waste packaging, and inspection of waste containers. The principal contaminants in the facility were plutonium, americium and uranium with less significant contributions from fission and activation products. The relative radionuclide content can vary significantly with each item and operation.

The worker started work in this facility on 1st of February 2014. The facility could contain uranic contaminants in a wide range of enrichments, including depleted uranium, natural, low and highly enriched uranium. The worker was placed on a routine confirmatory bioassay monitoring programme for reassurance that significant exposures (> 6 mSv per annum) were not missed by the primary assessment monitoring programme by Personal Air Sampler. The sampling programme included annual urine sampling for uranium analysis by alpha spectroscopy. The worker provided a first routine urine sample in May 2014; this sample produced a result greater than the pre-defined Investigation Level of 3 mBq/day (summed activity from ^{234}U, ^{235}U and ^{238}U).

There was no default *a priori* assumption of radionuclide mix. The chemical form was unknown; however, the facility could contain uranium contaminants in a range of chemical forms; materials with default (ICRP66) lung absorptions of Types F, M and S were feasible. The default *a priori* assumption for the monitoring programme was a lung absorption of Type S and an AMAD of 5 micrometres. Special urine samples were provided and were analysed for ^{234}U, ^{235}U and ^{238}U content by alpha-spectroscopy.

2.3.4 Case 4 : ^{241}Am

The fourth case, also adapted from a real event, was related to an accidental inhalation of ^{241}Am aerosol, followed by decorporation therapy using DiethyleneTriamine Pentaacetic Acid (DTPA).

In a radioactive waste treatment and disposal facility a worker opened a sealed drum containing radioactive wastes of ^{241}Am with activity levels in the giga-becquerel order of magnitude. The aim was to reduce the volume of the waste by sorting it according to the physical state and compressibility. The worker was supposed to wear a respiratory protective mask for this operation, but this was not checked nor proved. After the work was finished some contamination on his hands and clothes was detected.

Two days later the worker was subject to routine confirmatory monitoring by whole body counting, with the monitoring service being unaware of the incorporation event. Contamination with ^{241}Am was detected in the whole body spectra. This was the point at which the monitoring service became aware of the event. It turned out that some surfaces and clothes were also contaminated. He returned for repeated measurements on the ninth day after the event, following careful decontamination. Using profile scanning measurements it was found that the majority of contamination was located in the lung area.

Based on the results of these measurements an initial dose estimation was performed with the MONDAL code (Ishigure 2004), assuming inhalation as predominant intake pathway and ICRP

default parameter values, which was then reported to the authorities. Since the magnitude of the estimated committed effective dose exceeded the dose limit further investigations were decided. Follow-up investigation was continued, primarily in a dedicated institute, by direct chest counting and urine bioassay for an extended period. DTPA treatment started 19 days after the event. Efforts were also made to investigate the chemical and physical characteristics of the contaminant that comprised the intake.

The original compound was very probably americium-sulphate in soluble form, soaked up with filter paper and dried. This was the form of the contaminant when the drum was opened and the intake occurred. Because the contaminant became dusty the investigation determined it likely that the activity had been attached on particles and fibres that might be in the size range from a tenth of a micrometre to a few micrometres.

Data on lung and urine activities were available. Skin surface contamination was detected at the very beginning. Despite the strong efforts for the decontamination, it is possible that in the first one to two weeks this skin contamination influenced the lung activity measurements.

The secondary objectives for this case were for the assessor to determine which data should be used within the assessment, excluding those which might be affected by the DTPA treatment, and also to determine a 'real intake' – i.e. the actual initial intake; and an 'apparent intake' – i.e. a reduced value for the intake which would result from the assessment of the measurements performed after the end of the chelation therapy, such that this gives an indication of the beneficial effect of the therapy.

2.4 Time table of actions

Multiple activities have been performed for the development of the ICIDOSE 2017 intercomparison project, with the involvement of many contributors: the Core Group of experts (CG) who have taken care of the overall project and individually have the responsibility of the different case studies; Carlo-Maria Castellani (CMC), the Coordinator of the core group for the design and detailed planning of the actions; the Participants, for their deep involvement in the performance of the evaluations; Tamás Pázmándi (TP), in charge of collecting, organizing and compiling the submitted results; Augusto Giussani (AG), the on-site organizer of the workshop in BfS, Neuherberg; George Etherington (GE), the external reviewer of the intercomparison action (PHE, retired) and the Project Leader for the development of Recommendations as document RP188; and finally the Directorate-General for Energy of the European Commission (EC DG ENER) for the publication of the recommendations in the Radiation Protection Series of the European Commission as document RP188.

In Table 2-1 the chronology of the main actions related to the intercomparison action is summarized.

Table 2-1: Chronology of main actions performed during the period of the intercomparison action

Who	*Action*	*Date*	*End date*
CMC	Presentation of the Intercomparison action at the EURADOS WG7 meeting Oxford Main ideas	19/9/2016	
Core Group (CG)	Setting up the Core Group.	October 2016	
CG	Preliminary selection of cases to be evaluated: first web connect meeting	7/2/2017	
CMC	Presentation at the EURADOS WG7 meeting - Karlsruhe Description of the 4 selected cases	28/2/2017	
CG	Announcement of the ICIDOSE 2017 action in the EURADOS web site	12/4/2017	
AG	Requested and obtained formal permission of distribution of Final draft document of RP188, for intercomparison purposes, from EC DG ENER	17/5/2017	
Participants	Time for expression of interest by participants	1/6/2017	30/6/2017
CG	Preparation of the intercomparison exercise cases first Budapest meeting	7/7/2017	
AG	Distribution of the intercomparison materials (with final draft RP188 document) to the participants (link for download)	31/8/2017	
CMC	Presentation at the EURADOS WG7 meeting – Paris Descriptions of cases and response files 84 potential participants	9/10/2017	
Participants	Evaluation period for the participants	1/9/2017	15/12/2017
TP	Compilation of submitted results Distribution to the CG	20/12/2017	
CMC	Presentation at the EURADOS WG7 meeting - Lisbon Preliminary results 66 confirmed participants	6/2/2018	
CG	Second Budapest meeting: preliminary evaluation of results and Draft Report outline	12 and 13/4/2018	
CG	Preparation and presentation of a paper on preliminary results at the European IRPA Congress (The Hague, 4-8.6.2018)	May 2018	
CG	Submission of a paper note on the preliminary results to the journal Rad. Prot. Dos.	June 2018	

CG	Redaction of the EURADOS Draft Report	June -September 2018
EC DG ENER	Publication of the TECHREC recommendations as Radiation Protection 188	10/9/2018
CG	Preparation and presentation of a contribution on preliminary results at the HEIR 2018 Conference (Paris, 8-11.10.2018)	September 2018
CMC + CG	Presentation at WG7 meeting in Budapest Finalization of the Draft Report and next actions	28/9/2018
CMC	Distribution of the Draft Report to all participants	2/10/2018
AG, CG and Participants	Workshop with the participants at BfS in Munich Neuherberg	18-19 October 2018
GE + CG	Redaction of the discussion from the Workshop and improvements of RP188	15 /11/2018
GE + CG	Finalization of the ICIDOSE 2017 EURADOS Report	March 2019
GE + CG	Submission of a final paper in a peer review journal	Spring 2019

Several working meetings of the core group took place in different European cities during the period of the intercomparison (27/2-2/3/2017 Karlsruhe (D), 7/7/2017 Budapest (H), 6-8/2/2018 Lisbon (P), 12-13/4/2018 Budapest (H), 27-28/9/2018 Budapest (H)).

In addition several web connect meetings were held by the core group during the development of the intercomparison action, namely: 7/2/2017, 5/4/2017, 6/6/2017, 27/9/2017, 30/11/2017, 1/2/2018, 28/3/2018, 31/5/2018, 9/7/2018, 29/8/2018, 25/10/2018, 27/11/2018, 8/1/2019, 21/3/2019.

2.5 General intercomparison aims

The intercomparison exercise ICIDOSE 2017 was initiated, primarily, to check the practical applicability of the RP188 Recommendations. Four case studies, with different degrees of complexity, were developed and distributed to interested participants; the participants were requested to apply the RP188 Recommendations, in particular the parts related to Chapter E, to derive and submit solutions for the case studies. The submitted solutions were analysed collectively to determine how effectively the RP188 had been applied.

Additional statistical analyses were also conducted on the submitted results in order to derive useful information on the standard practices used in the internal dosimetry services as well as on common problems that may be encountered in their routine operation.

The following objectives were common to all of the case studies:

2.5.1 Provide estimates of intake and dose

Each case study required the participant to submit (an) estimate(s) of intake (Bq) and committed effective dose (mSv) according to their interpretation and application of RP188. These submitted results were then analysed collectively to provide statistical and graphical summaries, which were

used to determine how effectively the estimates can be considered to be harmonized (as described in the Scope in Chapter A of RP188).

2.5.2 Indicate the final step in RP188

The participants were requested to indicate at which step of the RP188 flowcharts and tables (as presented in Chapters E2 and E3 of the document) their assessment concluded. Similarly, if the case solution required the application of the IDEAS Guidelines (Castellani 2013), they were requested to indicate the corresponding final step of their analysis. This information was reviewed to determine the degree of consistency by which the procedural steps within RP188 have been followed.

2.5.3 Declare possession of any formal recognition

Participants were also requested to indicate whether the laboratory/organisation possessed any formal recognition for internal dose assessment: e.g. accreditation, approval, certification etc. This information was considered an interesting factor for the analysis of the submitted results, but was not included as a specific aim of the inter-comparison.

Further to the general aims and common objectives, as above, each case study identified additional specific aims, according to the particular features and problems associated with the case.

2.6 Case 1 specific aims

2.6.1 Implication of the use of new reference data from ICRP OIR publication Series

The background to the introduction of the ICRP OIR publication series is described in section 1.2. It is to be expected that the resultant changes to dose coefficients and bioassay functions will have a consequent impact when analysing incorporation measurements: i.e. the values provided in the OIR documents will lead to different results than those obtained using the values available up to now. This might even affect the procedures to be followed in the dose assessment.

An artificial case was created, as derived from OIR models and realistic uncertainties, corresponding to a hypothetical acute exposure to an airborne release of ^{60}Co aerosol. The data were chosen so that the significance test of Step 4 of RP188 Table E.1 (*Check if the 97.5% confidence level of the assessed projected annual dose is greater than 5% of the annual dose limit*) was verified with application of the OIR reference data, thus requiring to move to the special monitoring procedure, but not for the analysis according to ICRP 78, for which it would be sufficient to record the preliminary estimates of intake and dose.

The objective for this case was to assess how the use of different models might affect the evaluation process. Secondary objectives were to get acquainted with the application of the RP188 flowcharts and to identify the point within RP188 (i.e. the Step within ISO 27048, or Stage within IDEAS) at which the assessment concludes, when using bioassay functions and dose coefficients from ICRP Publications 78/119 or from ICRP OIR Publication Series.

2.7 Case 2 specific aims

Case 2 is derived from a real case of routine monitoring during the 1990s. This is considered as a typical dose calculation exercise to detect an unexpected intake in a particular monitoring period. One of the specific aims of this case was to identify and respond to the need for a transition from

routine to special monitoring. This can be accomplished by means of the correct use of the further two special monitoring results. Another specific aim was to apply the procedure for evaluating the contribution(s) of previous intake(s) in the results reported for routine monitoring measurements. This can be done by applying the test proposed on *P* (contribution from previous intakes) and *M* (measured value) in the second step of RP188 procedure.

The form that was provided to the participants for recording the results (smart pdf file) allowed for up to six intake regimes and exposure periods. It was also possible to indicate whether the intake was acute or chronic and the specific day (or interval) when an intake occurred. For each intake regime, partial intake and relative committed effective dose values were requested as well as the final steps reached in RP188 or IDEAS guidelines. The total estimated values (I and E(50)) had then to be reported on Table 3 of the same form.

Table 4 of the form is devoted to recording the detailed contributions from previous intakes. The participants were requested to fill in the table with the reference dates for up to five intakes, and the single contributions of each of them on the subsequent (up to the sixth) measurement values. This permits the evaluation of the total contribution to measurements and the net value due to a new intake, if any, in the monitoring period.

Therefore, the specific aims of the case can be indicated to be the verification of:

- Recursive intake and dose evaluation
- Detailed application of the RP188 approach

2.7.1 Verify the accuracy of recursive intake and dose evaluation

The application of a recursive dose assessment procedure in the case of routine monitoring can be verified by:

- Calculation of the contributions due to previous intakes.
- Use of two special monitoring measurements to confirm an unexpected intake detected by routine monitoring.
- Assumptions on the dates of intake set to calculate the contributions to subsequent monitoring measurements, both in the case of acute and chronic patterns of intake.

2.7.2 Detailed application of the RP188 approach

The detailed procedure of RP188 approach can be performed by:

- Verification of the final steps of RP188 for the first and second monitoring period (respectively routine and special monitoring).
- Verification of the accuracy of the application of RP188 test on comparison of measurements and contributions from previous intakes for the third and fourth routine monitoring period.

2.8 Case 3 specific aims

2.8.1 Comparison of initial and final estimates

Participants were asked to provide initial estimates of committed effective dose (mSv) and intake (Bq) based solely on the first urine sample result, as obtained from the confirmatory monitoring programme. The purpose is to compare these initial estimates against the final estimates (utilising

all the bioassay measurement data) to examine the effect of including special bioassay measurements in the final estimates.

2.8.2 Deriving estimates for a mix of multiple radionuclides

The Case Description included bioassay measurements for ^{234}U, ^{235}U and ^{238}U separately. The participants were requested to indicate how they had incorporated this data for individual radionuclides into estimates for total committed effective dose (mSv) and total intake (Bq). The form for submitting participants' results indicated four options:

- Separate individual direct estimates for each radionuclide, which are then summed to provide total intake and committed effective dose;
- A direct estimate from a single radionuclide, which is then used as a 'tracer' for intakes of the other radionuclides by application of the ratios displayed in the measurement data;
- Summation of the contributions from each radionuclide in the measurement data to provide a single total uranium value at each measurement date, which is then used to estimate intake and committed effective dose by application of a case-specific dose coefficient;
- Other means: a text box was included on the form to indicate the 'other' method used.

It is noted that the form gave no indication as to which method is recommended by RP188.

2.9 Case 4 specific aims

Case 4 is an extremely complicated accident case involving more complex issues (Pázmándi 2016), therefore several specific aims can be formulated in addition to the general one, i.e. checking the applicability of the procedures suggested by the RP188 document. In addition, the case also provides the opportunity to check the applicability of the structured dose assessment system of the previously developed IDEAS Guidelines.

Secondary aims were:

2.9.1 Requirements due to the received high dose

Referring to the text of RP188: "*If the analysis indicates that the annual dose limit may potentially be exceeded, it is recommended here that a more sophisticated analysis should be performed with the help of an expert. It is recommended that this more sophisticated analysis should follow the IDEAS Guidelines.*" Accordingly the participants were requested to perform the evaluation procedure with the highest possible accuracy due to the high value of the committed effective dose and its potential health and legal consequences.

2.9.2 Handling multiple types of bioassay data

Due to the requirement for a high level of accuracy in the dose assessment, multiple types of bioassay monitoring methods are advised to be applied. For this case the time-dependence of two sets of monitoring data were provided to the participants: ^{241}Am content in the lung, and activity concentrations in excreted urine samples. According to the IDEAS Guidelines: "*It is recommended, in cases where multiple types of bioassay data sets are available, that the intake and dose are assessed by fitting predicted values to the different types of data simultaneously.*" In this intercomparison participants were given a free choice to select their best dose estimate considering either a single data set, or both sets simultaneously. Participants were required to use

their own judgement in the selection of which monitoring data should be used in the evaluation process, based on the information provided in the case description

2.9.3 Considering the influence of decorporation therapy in the dose assessment process

The estimated high intake necessitated the application of DTPA chelation therapy in order to reduce the dose and the consequent potential health effects. In the course of the treatment the activity concentration of ^{241}Am is enhanced in the excreted urine for a longer time period, due to the effect of DTPA on the biokinetic behaviour. The initial degree of this increase is characterised by the enhancement factor. It also means that the time course of the excreted activities in this period differs from that which would result from the application of the default biokinetic model parameters, as recommended by ICRP. Therefore, based on ICRP recommendations, only those monitoring data for urine activities that are not influenced directly by the DTPA therapy can be used for intake and dose calculation. In the case description all monitoring data was provided to the participants, including those that have been measured during the decorporation treatment period. Important special aims were to understand the judgment of the participants on: which urine activity values can be assumed as not being influenced by the therapy; how to calculate the apparent intake; and how to estimate the best value of the committed effective dose.

2.9.4 Assessing real and apparent intakes and their use in dose estimation

The participants had to make their own choice on how to select appropriate urine data for their intake calculation and, consequently, how they could derive both real and apparent intakes. This had to be done considering the RP188 instructions: "*A baseline excretion may then be established that corresponds to an "apparent intake", which is equivalent to the real intake minus the activity removed by the therapy. ICRP biokinetic and dosimetric models could be applied to calculate the apparent intake and subsequently the dose."* The participants had to keep in mind that in the words of RP188: *"… the biokinetic behaviour will have been altered by the therapy and that the estimates of absorbed dose to organs and tissues may be biased. Strictly speaking, the reference dose coefficient is therefore not applicable. However, it may be used to obtain an estimate of the resulting doses."*

2.9.5 Deriving case specific biokinetic model parameter values

Since plenty of monitoring data were available, the task was to obtain a statistically acceptable fit of the biokinetic model to the monitored data. This required the participants to determine the optimum values of certain influencing parameters, following the structured procedure presented in the IDEAS Guidelines. Examples of influencing parameters are the AMAD, the absorption types or HRTM absorption parameters, the fractional absorption in the gastro-intestinal tract or HATM transfer factor. If the participant had varied some of the ICRP recommended reference parameters in order to assess the intake then they also had to consider these changes in the dose assessment process. According to the words of RP188: *"committed effective dose … should be calculated with the same model parameter values that have been used for the assessment of the intake, i.e. the ICRP default dose coefficients should not be used."*

2.9.6 Calculation of case specific dose coefficients

Different assessors might use their own approach to finding the optimum set of model parameter values in order to get a good fit to the measured data; therefore the calculated intakes might differ

considerably, together with the doses assessed with the same model parameter set. As a result a range of different case specific dose coefficient values could be expected.

2.9.7 Comparison and validation of the recent and previous ICRP recommended models and their parameters

At the time of this intercomparison exercise two different ICRP recommended HRTM models were available. All participants could have been expected to have access to existing publications: ICRP Publ. 66 (ICRP 1994a) and ICRP Publ. 130 (ICRP 2015); and some might also have had access to the draft text of Part 4 of the OIR Report Series (ICRP 2016b), containing element-specific recommendations. These documents contain different models and parameter values. Since this ^{241}Am case is well-documented with a known time of intake, it seems reasonable to use this exercise for comparing, checking and validating the models; and also to investigate the applicability of the recommended default parameters and material specific parameters in the dose assessment process of a real accidental case.

3. The dose assessment chapter of RP188 document

Chapter E of RP188 Recommendations is related to Routine and Special dose assessment and is divided into six sections, addressing the following topics:

- E1. Interpretation of monitoring data
- E2. Dose assessment and interpretation: Routine monitoring
- E3. Dose assessment and interpretation: Special monitoring
- E4. Monitoring and dosimetry for wound cases and cutaneous contamination
- E5. Monitoring and dose assessment in the event of decorporation therapy
- E6. Radiation protection for pregnant and breastfeeding workers

When performing the dose assessments of the four proposed cases the participants were asked to apply the sections E2 and/or E3, according to the specific case description.

The main flow chart of the procedure to be applied is reported the Figure E.1 of RP188, which is reproduced below as Figure 3-1.

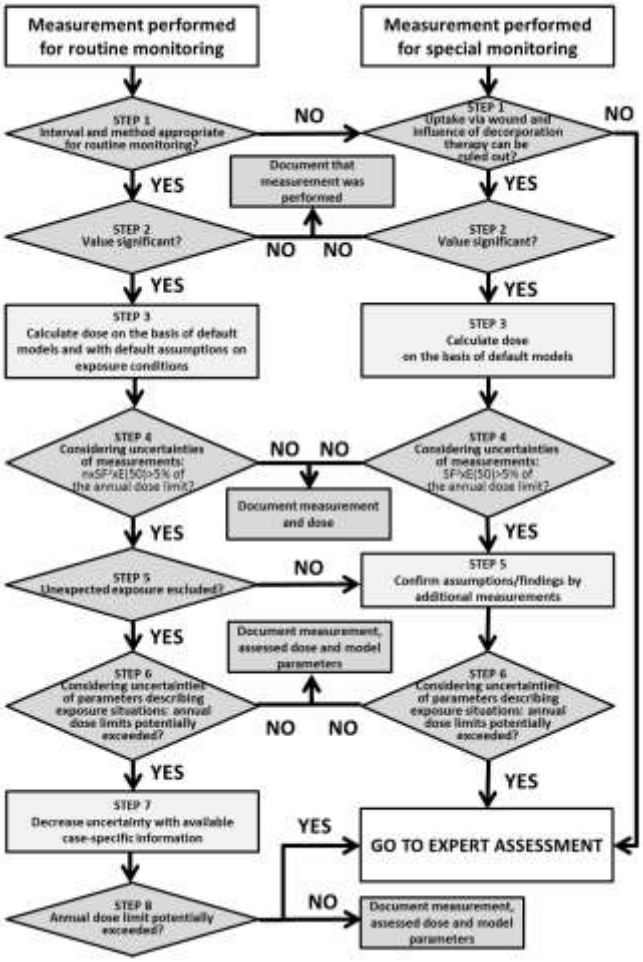


Figure 3-1: Procedure for assessment of doses on the basis of individual measurements

As can be seen from Figure 3-1 the two main paths refer to Routine monitoring (left part of the figure) and Special monitoring (right part of the figure) respectively. The two paths are linked at the

level of Step 5 of Routine monitoring: if during routine monitoring some unexpected exposure cannot be excluded then a jump to Step 5 of Special monitoring is recommended in order of confirm current assumptions by evaluating additional measurements results.

At four different stages of the evaluation the assessor is required to document the measurement, either alone or with the assessed dose and, in some circumstances, the model parameter values used.

Finally, if the committed dose of 20 mSv due to annual intake is adjudged to be potentially exceeded, given the measurements and the assumed specific case scenario, then step 8 of routine monitoring or step 6 of Special monitoring indicates the requirement to refer to expert assessment. This expert assessment is indicated to be Stage 4 of the IDEAS Guidelines (Castellani 2013), in which detailed dose assessment, following a step-by-step procedure, is further developed.

In the following paragraphs a detailed explanation of the application of sections E2 and E3 is presented. Two tables, which are reproduced here, give practical indications for the correct application of the flow charts of Figure 3-1.

3.1 Dose assessment in routine monitoring: section E2

Section E2 is dedicated to dose assessment in routine monitoring. The procedure indicated in Table 3-1 is designed to be applied on one routine measurement at a time, for all available results of routine monitoring, in an iterative way. This is why at the end of the evaluation, at step 8, after the documentation of committed effective dose and related parameter values, the evaluator is directed back again to the initial Step 1, in order to repeat the assessment for the subsequent routine monitoring period, and so on.

Table 3-1: Summary of RP188 procedure for dose assessment after routine monitoring

Step	Indication	Action or test	If test is verified	If test is NOT verified
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Verify that the monitoring method and interval are consistent with those indicated in ISO 20553:2006.	Go to Step 2	Go to Special Monitoring, Table E.2 – Step 1
2	Check if the monitoring value is significant	Check if the measured value exceeds both the decision threshold and the critical value for the type and interval of measurement. Test the significance of contribution(s) from earlier intake(s).	Go to Step 3	Document the measurement. No further dose assessment is needed.
3	Standard dose assessment	Perform standard dose assessment with default parameter values.	Go to Step 4	

4	Check if the 97.5% confidence level of the assessed projected annual dose is greater than 5% of the annual dose limit	Check if $E(50) > 1/(n \cdot SF^2)$ mSv	Go to Step 5	Document the intake for the monitoring interval and the related committed effective dose.
5	Check if unexpected exposures can be excluded (i.e. if the exposure is expected)	Check if the measurement is consistent with earlier experience; (site-specific quantitative criteria should be defined in advance).	Go to Step 6	Go to Special Monitoring, Table E.2 – Step 5.
6	Check whether dose *potentially* exceeds annual dose limit	Plot the measurement value on the band figures of Annex A of ISO 27048:2011, to check whether the annual dose limit may be *potentially* exceeded.	Go to Step 7	Document the intake for the monitoring interval, the related committed effective dose and the model parameter values.
7	Application of case specific information	Apply specific information to decrease the uncertainty of the assessment.	Go to Step 8	
8	Second check whether dose *potentially* exceeds annual dose limit	After having applied case-specific information, check again if the annual dose limit may potentially be exceeded.	Go to Stage 4 of IDEAS Guidelines	Document the intake for the monitoring interval, the related committed effective dose and the model parameter values. Go to Step 1.

The participants were expected to follow the different steps reported in the table until the evaluation logically terminates at a final step. The indication of the final step of evaluation was an integral part of the intercomparison exercise.

3.2 Dose assessment in Special monitoring: section E3

Section E3 is dedicated to dose assessment in special monitoring.

Table 3-2: Summary of RP188 procedure for dose assessment after special monitoring

Step	Indication	Action or test	If test is verified	If test is NOT verified
1	Check if an intake via wound, intact skin or influenced by decorporation therapy can be ruled out	Test is based on preliminary information.	Go to Step 2	Go to IDEAS-Guidelines, Stage 4 and follow wound route, or go to expert evaluation.
2	Check if the measured value is significant	Check if the measured value exceeds the decision threshold.	Go to Step 3	Document the measurement. No further dose assessment is needed.
3	Standard dose assessment	Perform standard dose assessment with default parameter values (time of intake is usually known).	Go to Step 4	
4	Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit	Check if $E(50) > 1/SF^2$ mSv	Go to Step 5	Document the intake and the related committed effective dose.
5	Confirm assumption and findings related to exposure scenario	Add additional special monitoring measurements.	Go to Step 6	
6	Check if the evaluated dose *potentially* exceeds the annual dose limit	Plot the measurement values on the band figures of Annex A of ISO 27048:2011, to check whether the annual dose limit may be potentially exceeded.	Go to IDEAS Guidelines - Stage 4	Document the intake, the related committed effective dose and the model parameter values.

The procedure, as summarized in Table 3-2, is intended to be applied to the result of the first bioassay measurement during a special monitoring programme instigated after a real or suspected incident or accident.

The procedure stops at Step 4 if the evaluated dose is negligible (less than $1/SF^2$ mSv) where SF is the total scattering factor related to the measurement result, calculated with equation F.6 at page 154 of RP188.

If the test of significance in Step 4 is not satisfied then the evaluation proceeds to Step 5 and additional results of bioassay measurements (and also for different bioassay types) are taken into account. At this step an analysis of the goodness of fit of the data to the model is also performed.

If the assessed committed effective dose potentially exceeds the annual dose limit the evaluation continues according to IDEAS GLs, Stage 4. Otherwise the evaluation stops with the record of the committed effective dose and the model parameter values used.

4. Overall statistics of participants

4.1 Overall statistical summary of participants

During June 2017 a period for expression of interest was opened to prospective participants to the intercomparison.

Eighty six participants indicated interest and were provided with the case descriptions. Sixty six participants from 26 different countries finally sent results. Fifty one of the participants were from Europe, and 15 participants were outside Europe (Figure 4-1 and Figure 4-2).

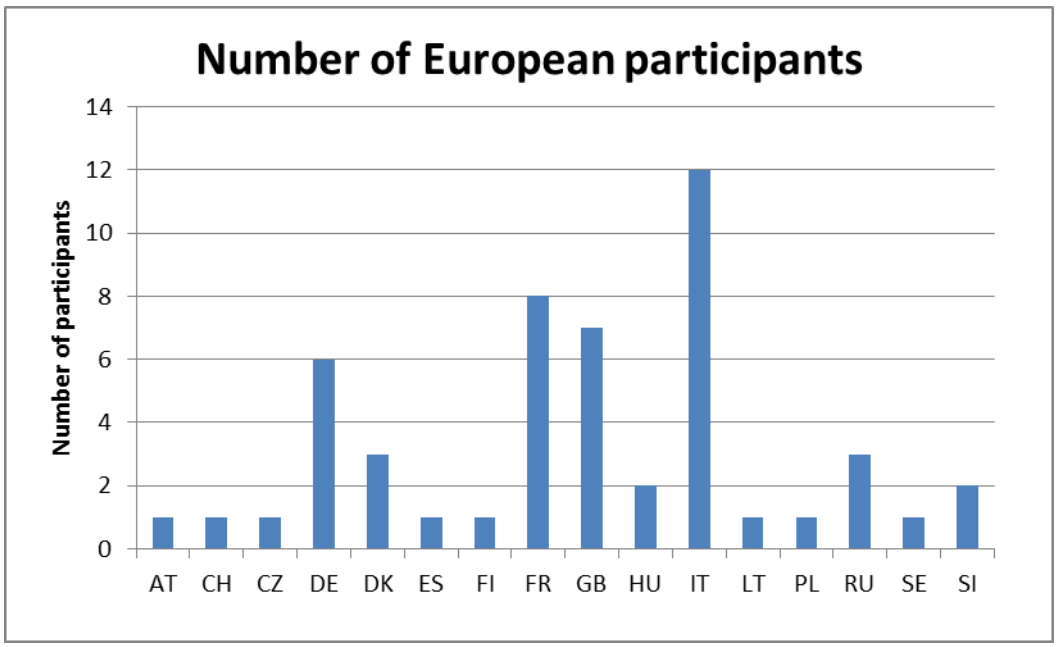


Figure 4-1: Number and origin country of the European participants. AT=Austria, CH=Switzerland, CZ=Czech republic, DE=Denmark, ES=Spain, FI=Finland, FR=France, GB=Great Britain, HU=Hungary, IT=Italy, LT=Lithuania, PL=Poland, RU=Russia, SE=Sweden, SI=Slovenia)

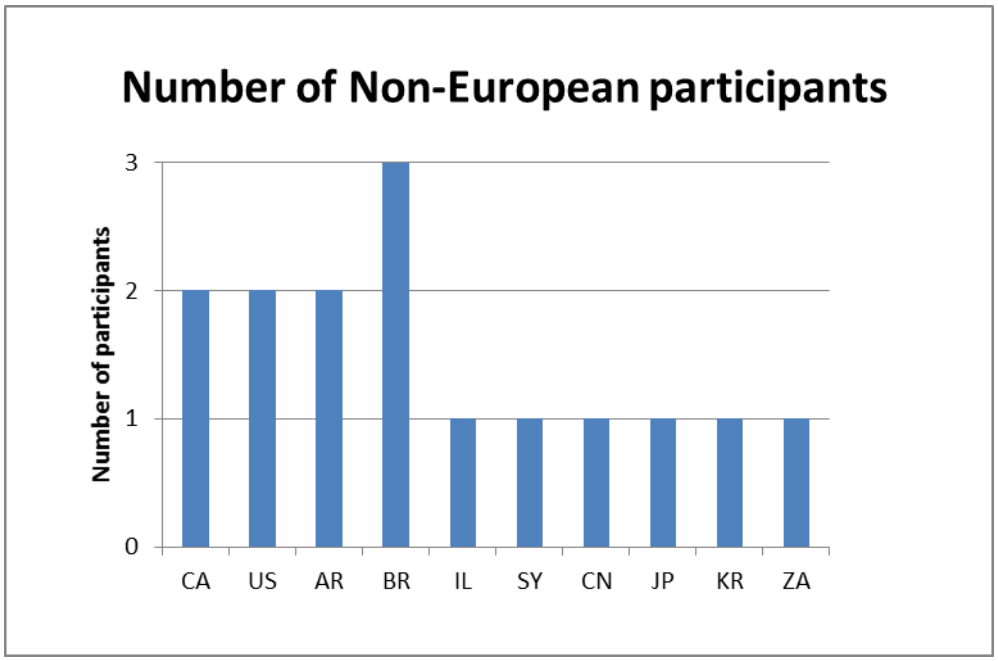


Figure 4-2: Number and origin country of the participants from outside Europe. (CA=Canada, US=United States of America, AR=Argentina, BR=Brasil, IL=Israel, SY=Syria, CN=China, JP=Japan, KR=Korea, ZA=South Africa)

In Table 4-1 the number of collected responses for each case is reported.

Table 4-1: Number of results submitted by case

Case number	Radionuclide	Number of submissions
1	^{60}Co	61
2	^{125}I	56
3	^{234}U+^{235}U+^{238}U	38
4	^{241}Am	31
ALL		186

The number of participants that submitted answers for various combinations of cases can be seen in Figure 4-3. 15% of the participants sent results for only one case, 29% for two cases, 15% for three cases and 41% answered for all four cases. On average, participants submitted results for three cases.

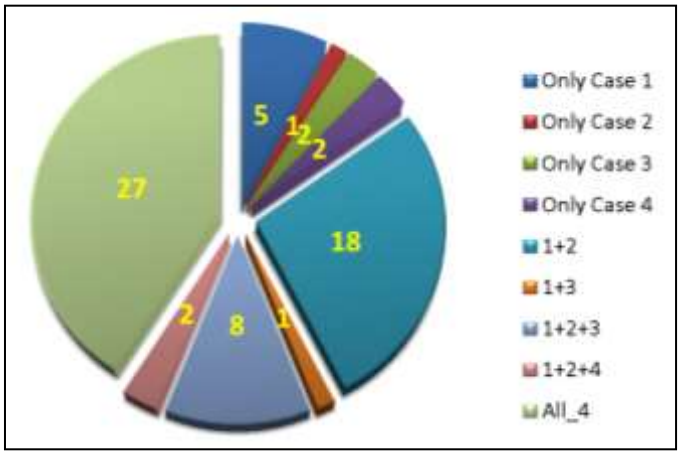


Figure 4-3: Number of participants answering the indicated cases

4.2 Methods for statistical evaluations

For the overall statistical evaluations two methods were applied to determine values for the central estimate and dispersion of the submitted solutions, both for assessed intake and committed effective dose:

i) calculation of the geometric mean (GM) and geometric standard deviation (GSD), assuming a log-normal distribution. Each value which diverges from the GM by a factor greater than 2.5 GSD is considered an outlier and excluded; the GM and GSD are then recalculated, and new outliers identified on an iterative basis until no further outliers remain. This is the statistical method applied to previous similar intercomparisons (IAEA 1999, 2007).

ii) application of robust statistic methods, according to ISO 13528 (ISO 2015a) and described in Annexe 3 "Robust statistics application".

The first method has been used to compare the spread of the results of the current study with those observed in previous intercomparison exercises.

The robust statistics approach has been used as the new reference method recommended for evaluation of intercomparison results.

In the following summary tables the ICIDOSE Reference Solution (henceforth reported as "Ref") is indicated together with the interval range of +/- a factor of three, which is considered to indicate the acceptable range of divergence from the ICIDOSE Reference Solution. The use of a factor of three is also considered to be consistent with the requirements of ISO20553 (ISO 2006), as applied to the design criteria for a routine monitoring programme; although it is acknowledged that, strictly considered, this criterion is not defined for the purpose of retrospective estimation of dose. The factor of three is, however, justified by the fact that, being that the investigation level is set at 30% of the annual limit and the recording level is set to 5% of the annual limit (ISO 2006), a dose that is around the investigation level will still be recorded, even in the case of maximum underestimation.

4.3 Structure of the following chapters

The following chapters (5 to 8) are addressed to each of the cases in sequence, and follow a similar format as below:

- Case description, based on the material provided to participants to describe the contamination scenario.
- Reference ICIDOSE Solution of the case (for cases 1, 2 and 3); and the Recommended ICIDOSE Solution (for Case 4)*: in which each step of the evaluation is presented.
- Overall measurements statistics for the submitted participant solutions
- Observations and discussion on selected aspects
- Errors performed by participants during the assessment .

** A 'Recommended Solution' is presented for Case 4 because the full, expert solution extends beyond the scope of RP188, and so is not strictly considered to be a 'reference solution' under RP188.*

5. Case 1

5.1 Case description

The event

Description of the working area

Plant for the production of cobalt sources.

Characteristics of work

Cobalt wires irradiated by neutrons in a nuclear reactor facility was used for the preparation of sealed ^{60}Co sources.

Reasons for monitoring; initiating event

An irradiated capsule containing ^{60}Co wire was opened in a hot cell, and after 10 minutes dose rate alarms sounded.

Initial actions taken

Operators closed the source, put on protective clothing and respirators, stopped the leakage and decontaminated the workplace. In-vivo monitoring was started one day after the event, urine samples were also taken.

Additional information

Air monitoring

No data available.

Chemical form

Cobalt oxide, AMAD 5 µm.

Physical characteristics, particle size

Aerosol.

Nose swab, bronchial slime or similar

None

Non removable skin contamination

None

Wound site activity

None

Any intervention used (blocking, chelating, etc.)

None

Individual monitoring data

Organ activity measurements:

None

Whole body activity measurements:

Whole body data are available. DL: 40 Bq

Excretion monitoring data

Urine activity measurements

Urine data are available.

Faeces activity measurement

None.

Personal Data

Sex

Male.

Age

39 y

Weight

77 kg

Other comments relevant for dose estimation

Evaluate the case considering retention curves and dose coefficients both from ICRP 72/78/119 series and from OIR series (see data provided).

Table 5-1: Case 1 whole body measurement data

Type of sample	*Time after intake (d)*	*Result*	*Percentage uncertainty (+/-2 sd)*	*units*
SPECIAL	1	18500	4%	Bq
SPECIAL	10	1875	5%	Bq
SPECIAL	30	1470	5%	Bq

Table 5-2: Case 1 urine measurement data

Type of sample	*Time after intake (d)*	*Result*	*Percentage uncertainty (+/-2 sd)*	*units*	*Comment*
SPECIAL	1	11.2	10%	Bq/d	spot sample / normalized
SPECIAL	10	0.3	15%	Bq/d	24-h collection

5.2 ICIDOSE Reference Solution

The ICIDOSE Reference solution is presented below, in table form, separately for the analysis using reference values from ICRP Publications 78/119 (ICRP 1997, 2012) and the analysis using reference

values from ICRP OIR Part 2 (ICRP 2016a). The format of Table 5-4 and Table 5-5 is a facsimile of the one used to summarise the procedural steps within RP188 Chapter E3. In both analyses presented below the preliminary checks are only made using the first whole body measurement. Only if the criterion of Step 4 is satisfied, then the remaining measured data are to be used.

5.2.1 Calculation of the scattering factors

For performing the checks described by the RP188 procedure it is first required to know the uncertainty of the measured values in terms of a scattering factor (see RP188 Chapter F). The scattering factor for Type A uncertainties (SF_A) is calculated using Eq. F.5 of RP188. The scattering factors for Type B uncertainties (SF_B) are taken from Table F.1 of RP188. The total scattering factor (SF) is calculated using Eq. F.6 of RP188 (see Table 5-3).

Table 5-3: Calculation of the scattering factors for the measurement data of Case 1

Type of sample	*Time after intake (d)*	*Result*	*Percentage uncertainty (+/-2 sd)*	*units*	*SF_A*	*SF_B*	*SF*
Whole Body	1	18500	4%	Bq	1.02	1.15	1.15
Whole Body	10	1875	5%	Bq	1.03	1.15	1.15
Whole Body	30	1470	5%	Bq	1.03	1.15	1.15
Spot urine sample	1	11.2	10%	Bq/d	1.05	2.0	2.0
24-h urine sample	10	0.3	15%	Bq/d	1.08	1.1	1.13

5.2.2 Solution using ICRP Publication 78

First Monitoring result: 18500 Bq ^{60}C0 in whole body

Table 5-4 : adapted from RP188: Table E.2 Summary of ISO 27048:2011 procedure for Special Monitoring

Step	Indication	Result	Notes
1	Check if an intake via wound, intact skin or influenced by decorporation therapy can be ruled out	The case description does not indicate any of these occurrences, so they can be ruled out	Go to step 2
2	Check if the measured value is significant	Value M is > DL=40 Bq so M > DT = 20 Bq (as indicated in Table 3.4 of IDEAS Guidelines)	Go to step 3
3	Standard dose assessment	m(T=1 d) = 0.49 Bq/Bq intake I = 18500/0.49 = 37755 Bq e(50) = 1.7 E-08 Sv/Bq E(50) = 0.642 mSv.	Go to step 4

4	Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit	5% of 20 mSv is 1 mSv Relation to be tested: E(50) > 1 mSv / SF^2 SF = 1.15 $1/SF^2 = 0.756$ E(50) is less than $1/SF^2$ 97.5% CL of the evaluated effective dose is lower than 5% of annual dose limit	Document the intake and the committed effective dose

5.2.3 Solution using ICRP OIR Part 2 (ICRP Publication 134)

First Monitoring result: 18500 Bq $^{60}C0$ in whole body

Table 5-5: adapted from RP188: Table E.2 Summary of ISO 27048:2011 procedure for Special Monitoring

Step	Indication	Result	Notes
1	Check if an intake via wound, intact skin or influenced by decorporation therapy can be ruled out	The case description does not indicate any of these occurrences, so they can be ruled out	Go to step 2
2	Check if the measured value is significant	Value M is > DL=40 Bq so M > DT = 20 Bq (as indicated in Table 3.4 of IDEAS Guidelines)	Go to step 3
3	Standard dose assessment	m(T=1 d)) = 0.614 Bq/Bq intake I = 18500/0.614 = 30130 Bq e(50) = 3.1 E-08 Sv/Bq E(50) = 0.934 mSv.	Go to step 4
4	Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit	5% of 20 mSv is 1 mSv Relation to be tested: E(50) > 1 mSv / SF^2 SF = 1.15 $1/SF^2 = 0.756$ E(50) is greater than $1/SF^2$ 97.5% CL of the evaluated effective dose is greater than 5% of annual dose limit	Go to step 5
5	Confirm assumption and findings related to exposure scenario Add additional special monitoring measurements.	**Two additional whole body measurements** and **two urine measurements** are available.	Go to step 6
6	Check if the evaluated dose potentially exceeds the annual dose limit	As there is no plot for the predictions with the OIR biokinetic models, equation E.8 is used for all available measurements: 18500 < 89600 **YES**	Table E.2 says: Document the intake, the related committed effective dose and the model parameter values.

		1875 < 8040 **YES** 1470 < 7360 **YES** 11.2 < 16 **YES** 0.3 < 2.66 **YES**	
	Document the intake, the related committed effective dose and the model parameter values.	Intake can be calculated using equation E.9: I = 25821 E(50) = 0.800 mSv	Following the indication of Table E.2 the analysis could finish here. However, the RP188 text clearly states that the goodness of fit must be checked (section 6.3 of IDEAS Guidelines).
	Calculation of chi-square and test of goodness of fit	Chi-square = 17.1956 degree of freedom = 4 P = 0.00177 Fit is rejected	Looking at the Chi-Square we can notice that the last urine point has the greater contribution to the Chi-Square. Check whether this data point can be considered a rogue data
	Identification of rogue data/outliers (Section 6.1 of IDEAS Guidelines - Version 2)	Calculation of intake with Equation E.9 using only WB measurements and first urine measurement. I = 31034 Bq m(10) = 1.75E-05 I*m(10) = 0.543 Bq M = 0.3 $I*m(10)/SF^3 = 0.543/(1.13)^3 = 0.38$ 0.3 < 0.38 The last point is an outlier.	One criterion given for identification of an outlier is to check whether the measurement value M(t) is more than a factor of SF^3 away from the trend of the other data: $M < I*m/SF^3$ or $M > I*m*SF^3$ Having demonstrated that the last point is an outlier, the goodness of the fit obtained excluding the outlier needs to be checked
	Calculation of chi-square and test of goodness of fit	Chi-square = 0.6674 degree of freedom = 3 P = 0.881 Fit is accepted I = 31034 Bq E(50) = 0.962 mSv	The fit is accepted. The intake and dose should be documented. The analysis is terminated here.

5.3 Overall measurements statistics for the participant solutions

5.3.1 Intake - Analysis according to ICRP 78.

In Figure 5-1 the distribution of the intakes estimated using the reference data of ICRP 72/78/119 is presented. The corresponding statistical parameters are given in Table 5-6. Figure 5-2 displays a histogram with the single values submitted by each participant, identified by the ID-number (PID). The X axis crosses the Y axis at 37755 Bq, i.e. the ICIDOSE reference value.

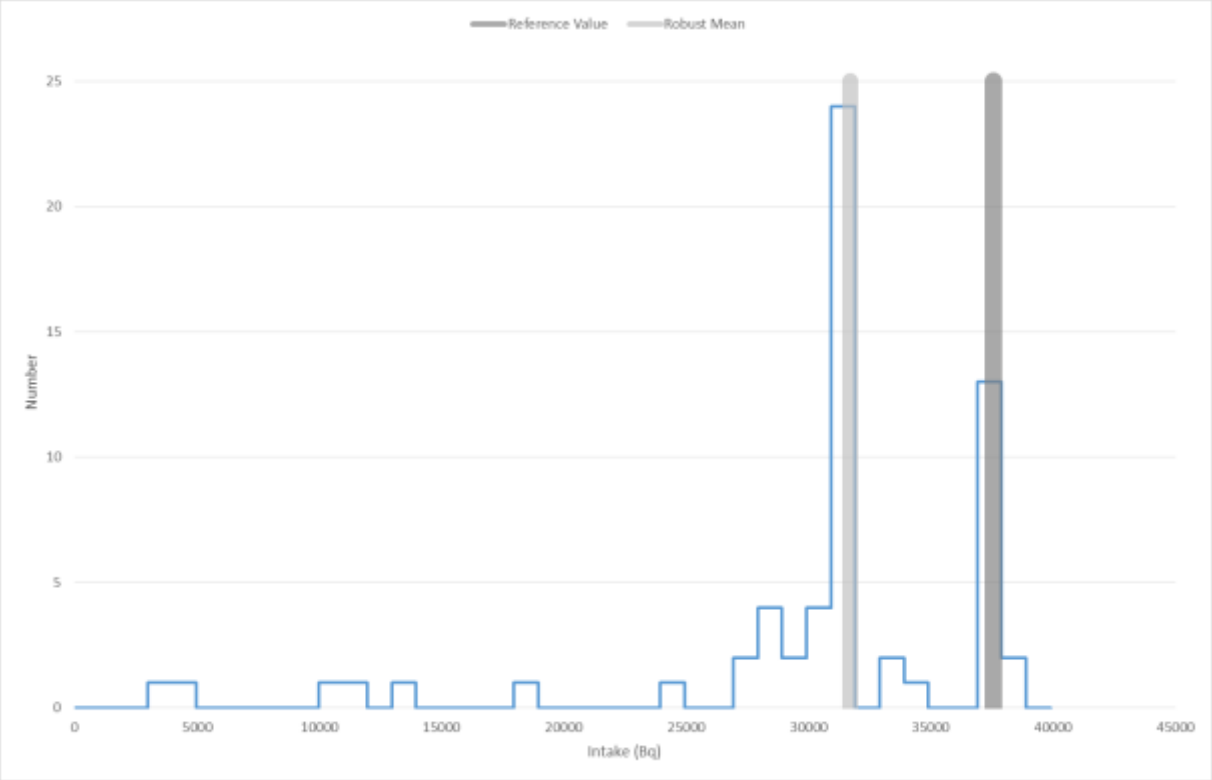


Figure 5-1 : Distribution of intake values according to ICRP 78

Table 5-6: Overall statistics of solutions submitted for estimates of intake according to ICRP 78

Number of submissions	61
Quantity	Intake
Unit	Bq
Parameters excluding outliers	
GM	3.23 E+04
GSD	1.12
Number of outliers	6
Parameters including outliers	
Min	3.78 E+03
Max	3.80 E+04
Ratio Max/Min	10
Robust mean (RM)	3.17 E+04
Robust st. dev. (RSD)	4.69 E+03
RSD / RM (%)	14.8
ICIDOSE Reference value (Ref)	**3.78 E+04**
Ref/3	1.25 E+04
Ref*3	1.13 E+05
Number of data less than Ref/3	4
Number of data greater than Ref*3	0

Two main modes can be identified from Figure 5-1: a major one around 31 kBq (with a small tail around 28 kBq) and a minor one around the "reference value" of 38 kBq. The robust mean coincides approximately with the major mode. The peak around 31 kBq can be explained by considering that some participants did not stop the evaluation procedure after verifying that the 97.5% CL of the committed effective dose E(50) - estimated with the first measured value - was less than 5% of the annual dose limit. Rather, they have used all whole body measurements for estimating the intake. Indeed, a value of 30973 Bq is obtained in this case following the RP188 procedure. The participants should have noticed, however, that the whole body data were not consistent with the urine measurements and thus should have questioned the model assumptions. Actually a number of participants have used non-default values for lung absorption, probably as an attempt to better describe the data.

Six values were identified as outliers (see Figure 5-2), four of them are less than one third of the reference value. In spite of a ratio between maximum and minimum value of 10, the GSD is rather narrow (1.12) as well as the ratio RSD/RM (0.15). If we considered that participant 65 committed a mistake in typing the value of the intake (its result is actually exactly a factor 10 lower than the reference value, but the provided dose value is correct) the ratio of maximum to minimum would reduce to 7.8, and the number of results lower than one third of the reference value would reduce to three.

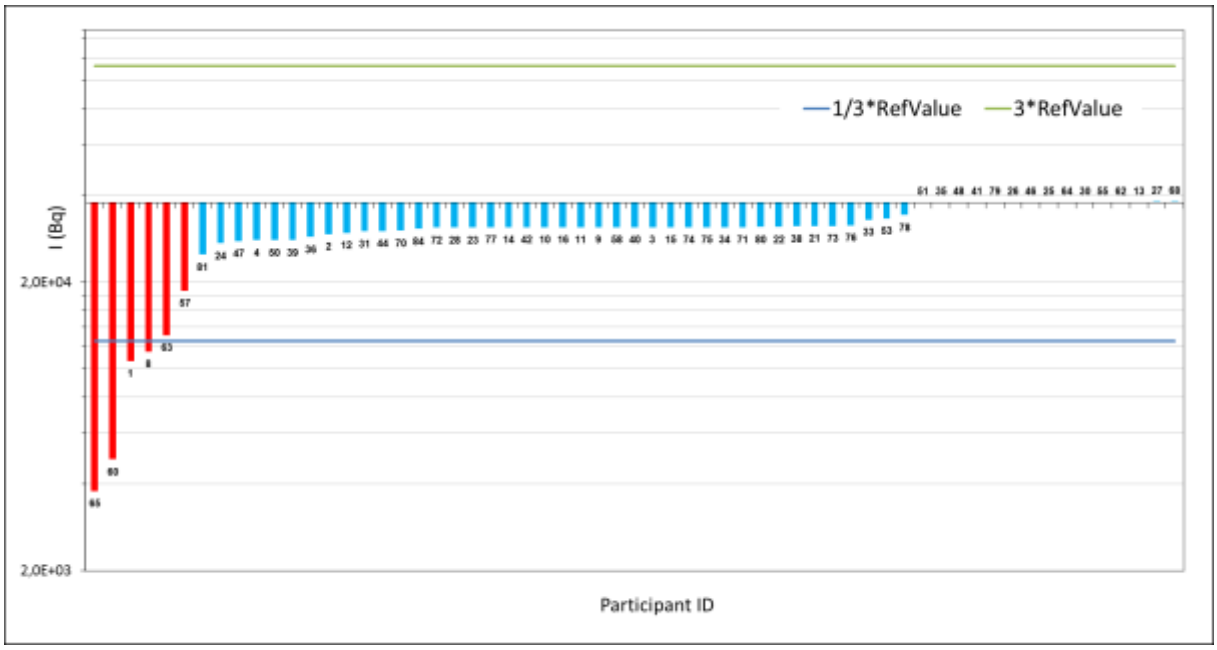


Figure 5-2: Histogram of intake values according to ICRP 78. Outliers are indicated in red.

5.3.2 Dose - Analysis according to ICRP 78.

In Figure 5-3 the distribution of the committed effective dose estimated using the reference data of ICRP 78/119 is presented. The corresponding statistical parameters are given in Table 5-7. Figure 5-4 displays a histogram with the single values submitted by each participant, identified by the PID number. The X axis crosses the Y axis at 0.642 mSv, i.e. the ICIDOSE reference value. It must be noted that two participants have provided the dose result in Sv instead of mSv. These values have been corrected before analysis. Table 5-7 shows that the statistical parameters considered are not affected by these two incorrect results.

Also for the committed effective dose a bimodal distribution can be seen, corresponding to the distribution of the intake. Nearly all participants have indeed used the correct dose coefficient. The number of outliers (9) is not negligible, only four of them are outside the range [1/3 * Ref; 3* Ref]. The ratio between maximum and minimum (12.5) is similar to the one observed for intake, as is the ratio RSD/RM (0.17).

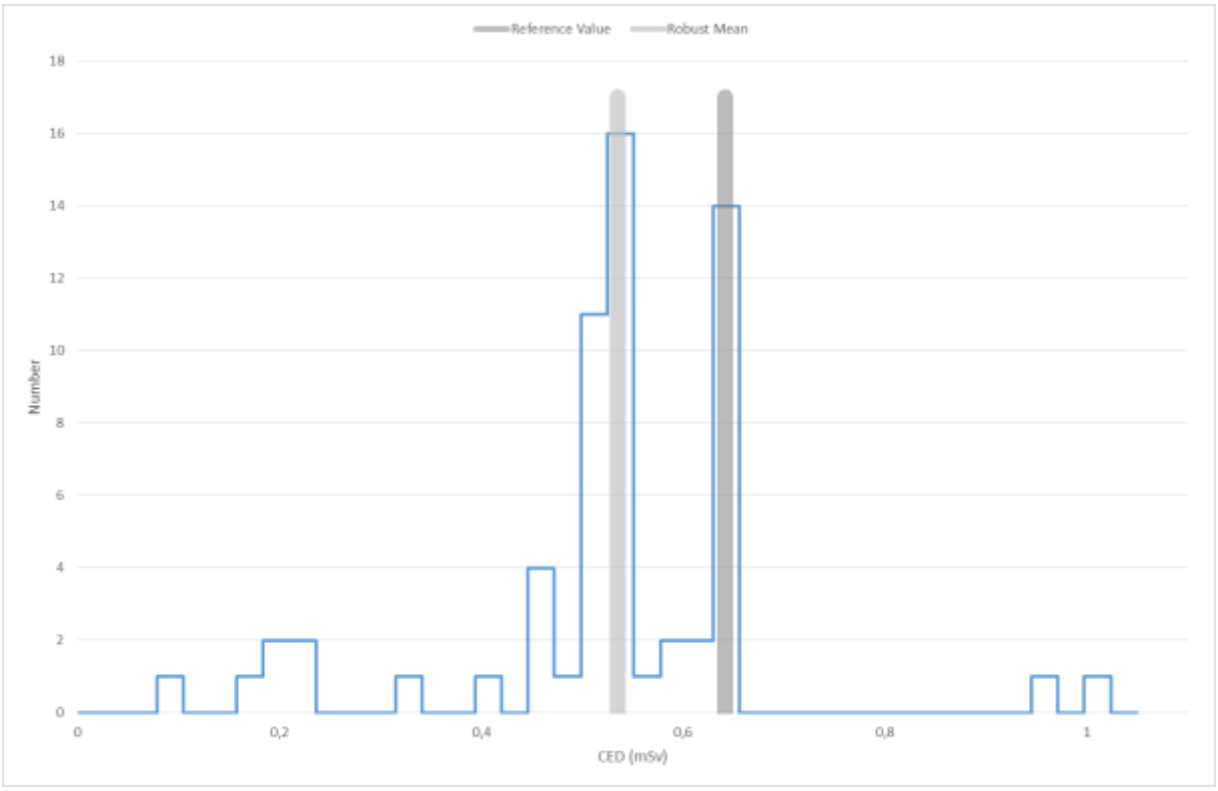


Figure 5-3: Distribution of committed effective dose values according to ICRP 78.

Table 5-7: Overall statistics of solutions submitted for estimates of committed effective dose according to ICRP 78.

Number of submissions	61	
Quantity	Dose	
Unit	mSv	
Data used	submitted	corrected
Parameters excluding outliers		
GM	0.549	0.548
GSD	1.13	1.12
Number of outliers	10	9
Parameters including outliers		
Min	3.2 E-04	0.08
Max	1.0	1.0
Ratio Max/Min	3.1 E+03	12.5
Robust mean (RM)	0.535	0.539
Robust st. dev. (RSD)	0.098	0.092
RSD / RM (%)	18.3	17.0
ICIDOSE Reference value (Ref)	**0.642**	
Ref/3	0.21	
Ref*3	1.93	
Number of data less than Ref/3	7	5
Number of data greater than Ref*3	0	0

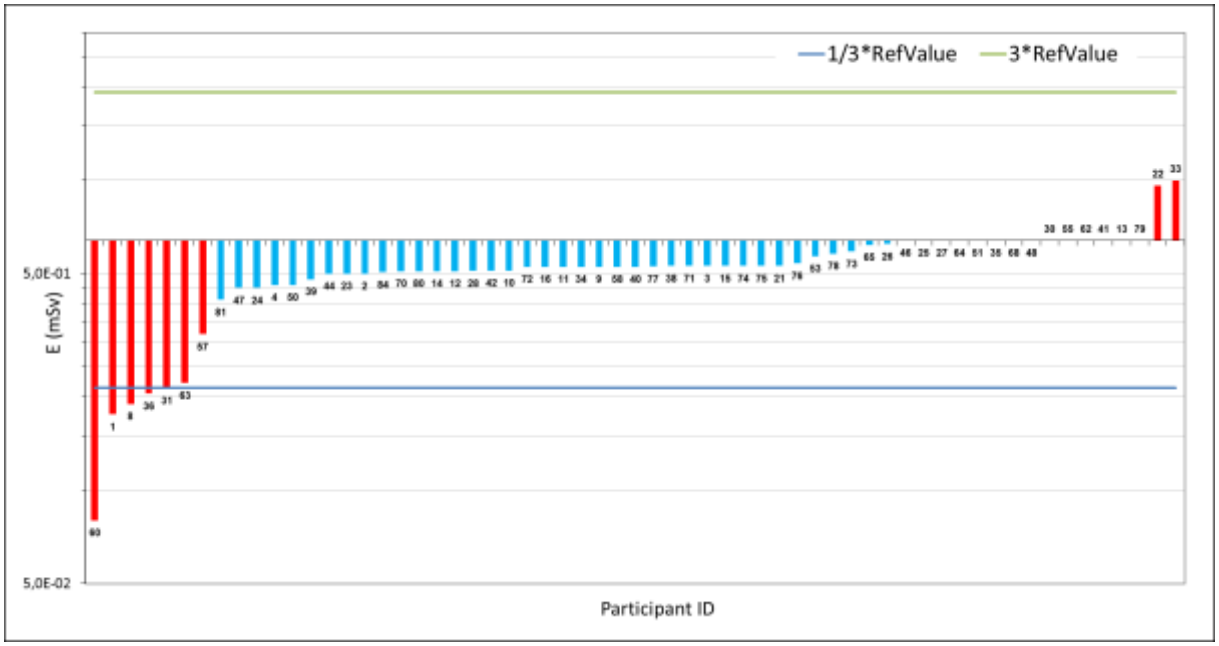


Figure 5-4: Histogram of committed effective dose values according to ICRP 78. Outliers are indicated in red.

5.3.3 Intake - Analysis according to ICRP OIR.

In Figure 5-5 the distribution of the intakes estimated using the ICRP OIR data is presented. The corresponding statistical parameters are given in Table 5-8. Figure 5-6 displays a histogram with the single values submitted by each participant, identified by the PID number. The X axis crosses the Y axis at 31034 Bq, i.e. the ICIDOSE reference value.

Figure 5-5 shows that in this case the robust mean of the submitted data is very close to the reference value; all data are included in a very narrow range around the reference value of 31 kBq.

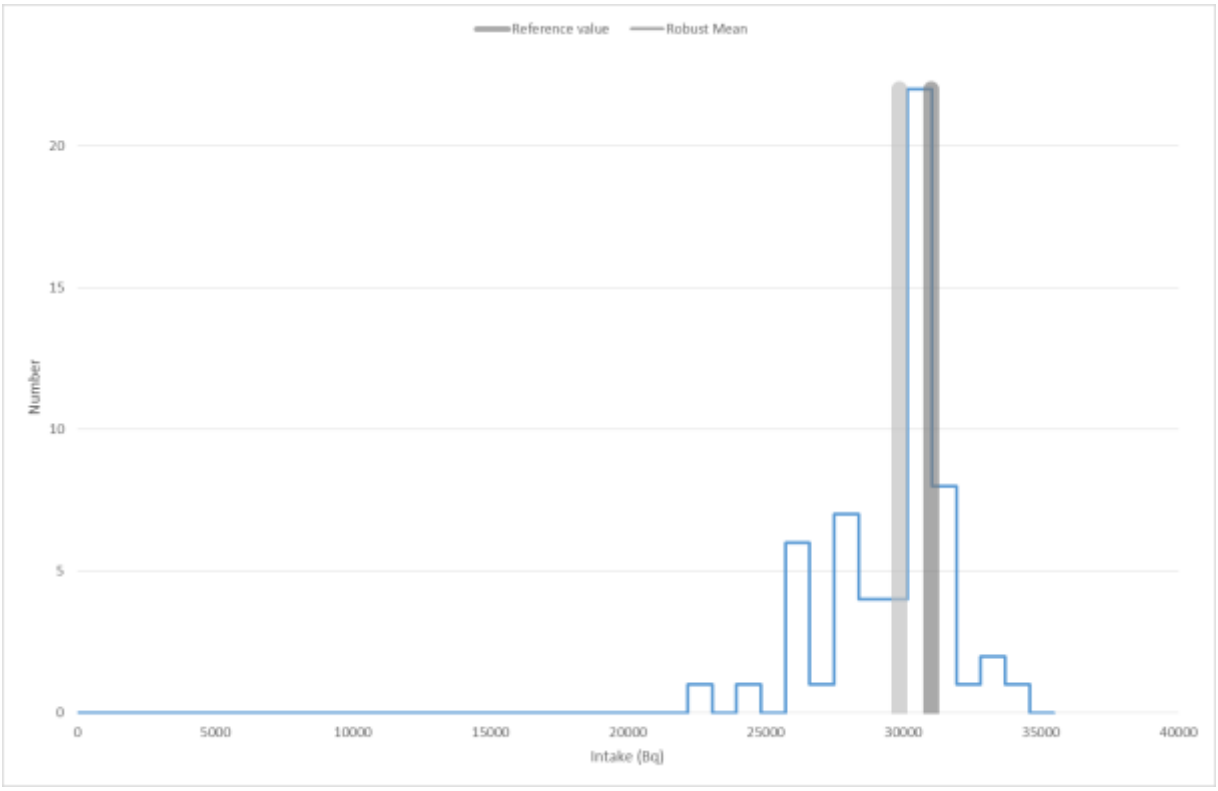


Figure 5-5: Distribution of intake values according to ICRP OIR.

Table 5-8: Overall statistics of solutions submitted for estimates of intake according to ICRP OIR.

Number of submissions	58
Quantity	Intake
Unit	Bq
Parameters excluding outliers	
GM	2.99 E+04
GSD	1.07
Number of outliers	2
Parameters including outliers	
Min	2.25 E+04
Max	3.38 E+04
Ratio Max/Min	1,50
Robust mean (RM)	2.99 E+04
Robust st. dev. (RSD)	2.01 E+03
RSD / RM (%)	6.7
ICIDOSE Reference value (Ref)	**3.10 E+04**
Ref/3	1.03 E+04
Ref*3	9.31 E+04
Number of data less than Ref/3	0
Number of data greater than Ref*3	0

The narrowness of the distribution, with all values well inside the range [1/3 * Ref; 3* Ref], and a ratio for maximum to minimum of only 1.50, are the reasons why two values are identified as outliers, although they are close to the trend of all other data. The GSD is equal to 1.07, and the ratio RSD/RM is 0.07.

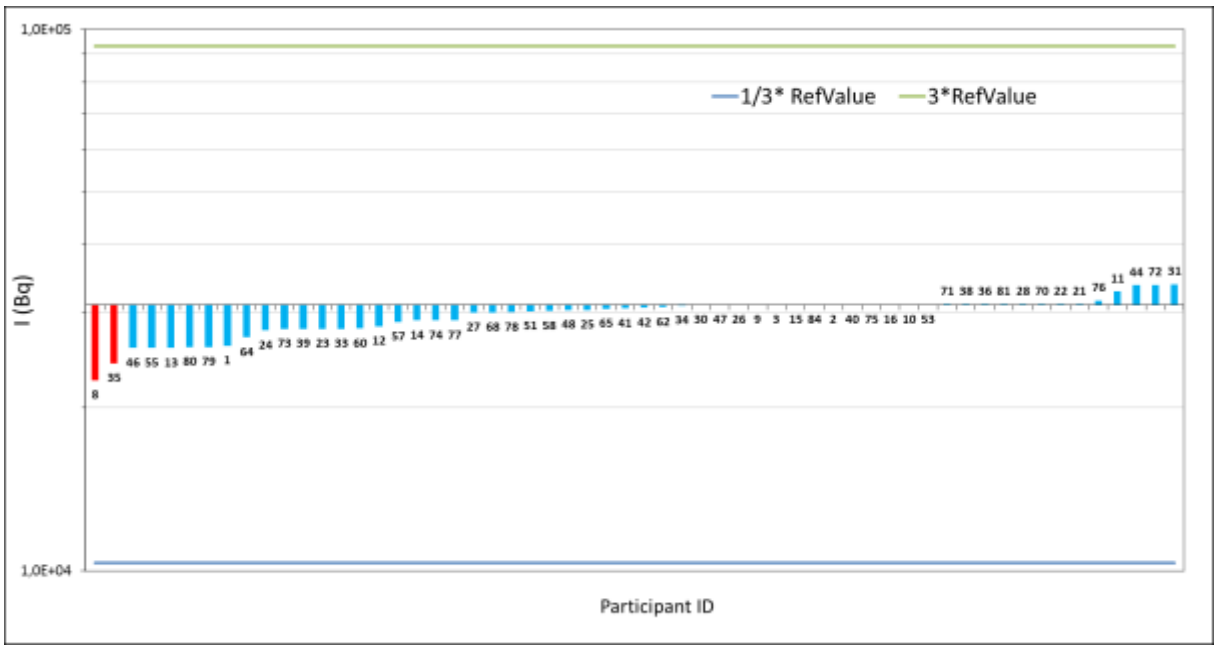


Figure 5-6: Histogram of intake values according to ICRP OIR. Outliers are indicated in red.

5.3.4 Dose - Analysis according to ICRP OIR.

In Figure 5-7 the distribution of the committed effective doses estimated using the ICRP OIR data is presented. The corresponding statistical parameters are given in Table 5-9. Figure 5-8 displays a histogram with the single values submitted by each participant, identified by the PID number. The X axis crosses the Y axis at 0.962 mSv, i.e. the ICIDOSE reference value. One participant has provided the dose result in Sv instead of mSv; this value has been corrected before the analysis. Table 5-9 shows that the reported statistical parameters are not affected by this incorrect result.

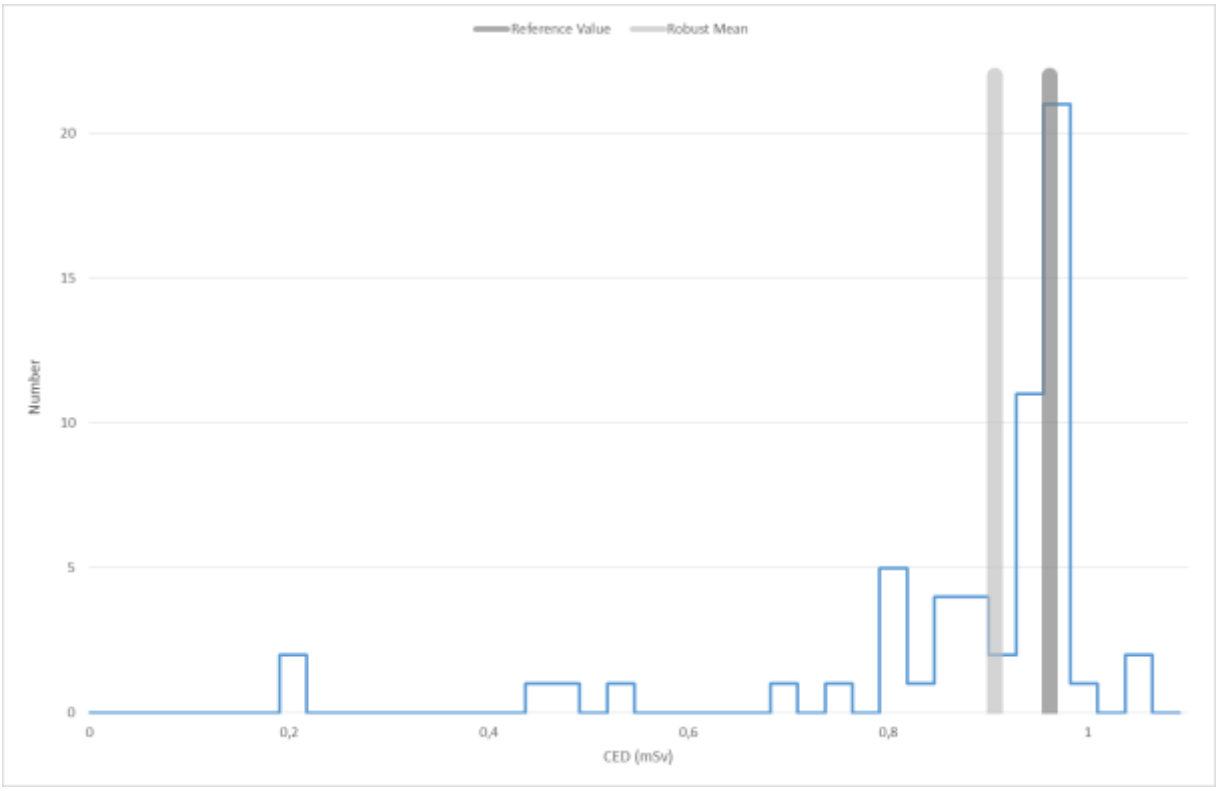


Figure 5-7: Distribution of committed effective dose values according to ICRP OIR.

Table 5-9: Overall statistics of solutions submitted for estimates of committed effective dose according to ICRP OIR.

Number of submissions	58	
Quantity	Dose	
Unit	mSv	
Data used	submitted	corrected
Parameters excluding outliers		
GM	0.925	0.925
GSD	1.07	1.07
Number of outliers	8	7
Parameters including outliers		
Min	0.001	0.204
Max	1.04	1.04
Ratio Max/Min	1.16 E+03	5.1
Robust mean (RM)	0.907	0.910
Robust st. dev. (RSD)	0.082	0.077
RSD / RM (%)	9.0	8.5
ICIDOSE Reference value (Ref)	**0.962**	
Ref/3	0.321	
Ref*3	2.886	
Number of data less than Ref/3	3	2
Number of data greater than Ref*3	0	0

Figure 5-7 and Table 5-9 show that for the committed effective dose there is a fair agreement between the reference value and the statistical quantities: robust mean and geometric mean. However, due to some of the participants using dose coefficients that are different from the reference, there are a number of values which are significantly lower than the ICIDOSE reference. There are seven outliers, and two values outside the range [1/3 * Ref; 3* Ref]. The ratio of maximum to minimum is 5.1, which is much larger than the value of 1.5 found for intake. The GSD (1.07) and the ratio RSD/RM (0.085) are not very different from the values found for the intake.

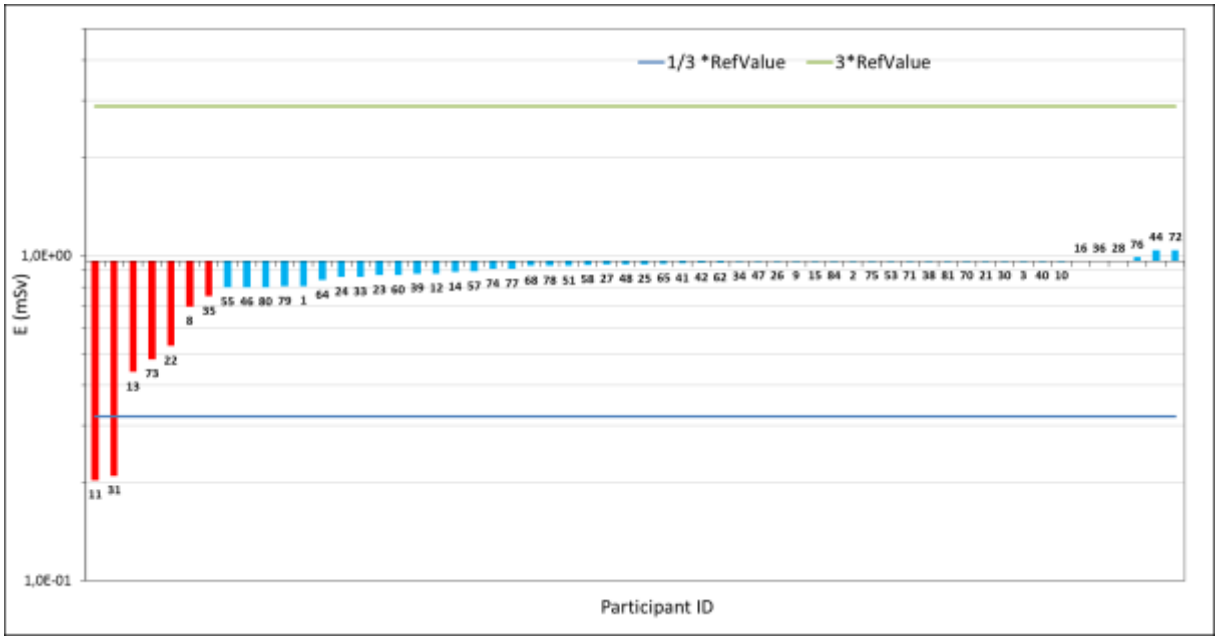


Figure 5-8: Histogram of committed effective dose values according to ICRP OIR. Outliers are indicated in red.

5.4 Observations and discussion on selected aspects

Apparently many participants have performed their analysis using, from the beginning, the whole set of available data instead of starting with the checks described in Table E.2 of RP188 and using only the first whole-body measurement. The fact that all data were made available to the participants in the case description may well have led them to believe that all data had to be used from the beginning. However, the philosophy of the recommendations is that the first checks (Steps 1-4 of Table 2) are to be done on the first value, and only if the potential exposure is above a certain threshold, further measurements are then taken into consideration. This is in order to keep the complexity of the procedure proportional to the magnitude of the exposure.

5.4.1 *Comparison between accredited and non-accredited centres*

The fact that institutions had some kind of certification does not seem to play any role in the accuracy of the submitted results. This can be clearly seen in the two following figures, where the distributions of the committed effective doses estimated according to ICRP 78 (Figure 5-9) and according to ICRP OIR (Figure 5-10) are plotted separately for centres with and without accreditation.

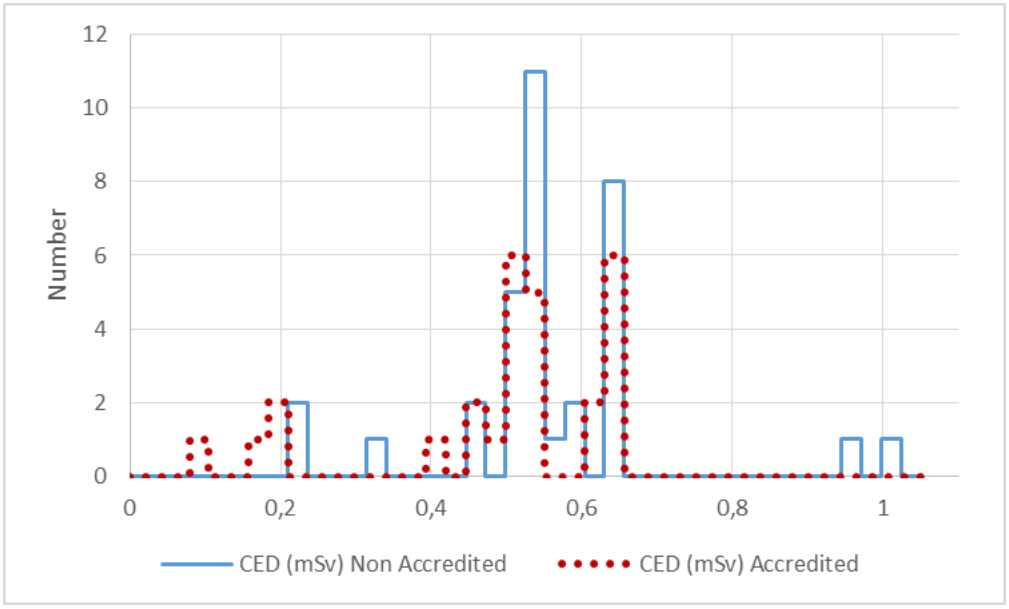


Figure 5-9: Comparison of the distribution of the results (committed effective dose estimated according to ICRP 78) between centres with accreditation (dotted red line) and without accreditation (solid azure line).

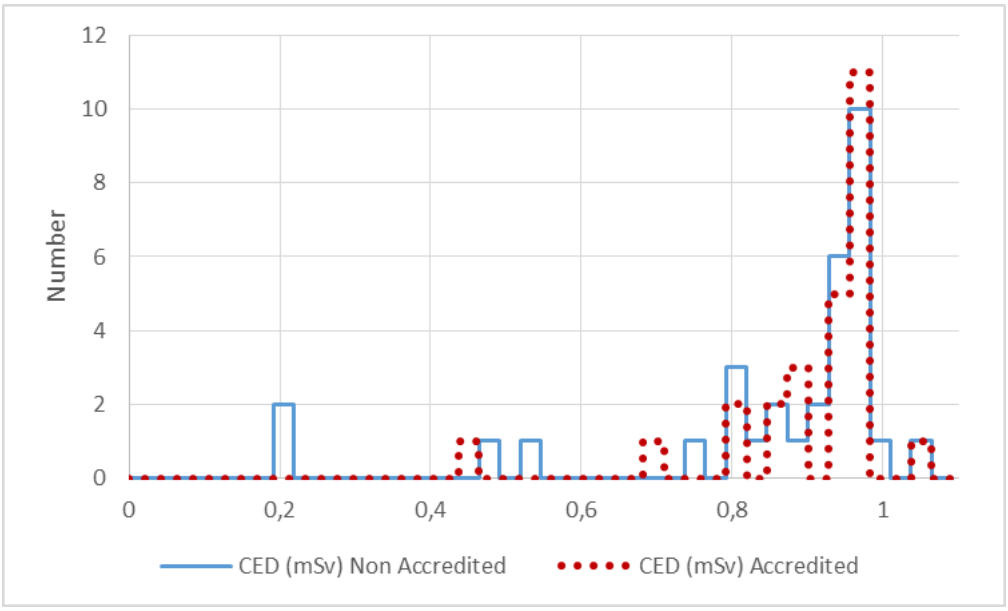


Figure 5-10: Comparison of the distribution of the results (committed effective dose estimated according to ICRP OIR) between centers with accreditation (dotted red line) and without accreditation (solid azure line).

5.4.2 *Use of Software*

One of the questions for the participants was whether they had used software for solving the case. For the solution according to ICRP OIR, only eight participants have declared the use of software. One of them used IMBA, one used BIOKMOD and two others do not mention which software they have used. The remaining four used an Excel Worksheet, which is actually not a specific software for internal dosimetry assessment, rather a tool for facilitating calculations by hand. It is not surprising that so few participants used software, since no commercial software is actually available which already includes the reference data of the OIR publication(s). This lack of dedicated software did not prevent the participants from providing good quality results, particularly for the estimates of intake.

On the other hand, 36 participants out of 61 (59 %) indicated that they had performed the analysis according to ICRP 78 with the help of software. The majority of them, 24, used IMBA (different versions and releases of the software are indicated), four participants used AIDE, three used MONDAL and one participant each used CALIN, IDEA-SYSTEM or OPSCI. Again, two participants indicated Excel as if it were an internal dosimetry software, but it is only a calculation tool.

It is interesting to note from Figure 5-1 that the results of those participants who did not make use of software (solid azure line) are equally peaked around the ICIDOSE reference value and the other peak of the bimodal distribution described in 5.3.2. Conversely, the distribution of the results provided by the participants who have used software (dotted red line) is significantly biased towards the lower value. This result is not surprising, considering that no software is currently available that follows the RP188 procedure, so the automatic routines of the program might have directed the solution towards a value different from the ICIDOSE reference. Moreover it is likely that participants using a software tool have analyzed the case considering all available data from the beginning, without performing the initial checks on the first available monitoring data only. Since the data for this artificial case were created using the new models from the OIR publication, it is also likely that the software packages, which are based on models and bioassay functions from the old publications, might have encountered problems in analyzing the data.

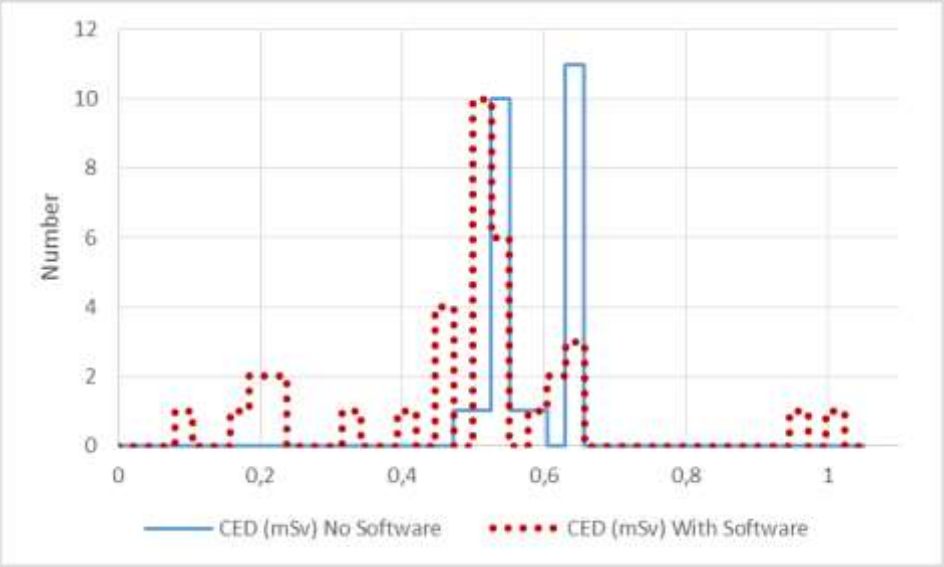


Figure 5-11: Comparison of the distribution of the results (committed effective dose estimated according to ICRP 78) between participants using a software (dotted red line) and without a software (solid azure line).

5.4.3 *Step at which the analysis was terminated*

For the analysis according to ICRP 78, the majority of participants correctly stop their evaluation at Step 4 of the RP188 procedure for Special Monitoring (see Table 5-10).

Table 5-10: Terminating step in RP188 as reported for analysis according to ICRP 78

Terminating Step	*Number of submissions*	*(%)*
RP188: Section E2 (Routine) Step 4	3	4.9
RP188: Section E2 (Routine) Step 6	1	1.6
RP188: Section E3 (Special) Step 1: IDEAS: Stage 5A Step 5.6.1	2	3.3
RP188: Section E3 (Special) Step 3	1	1.6
RP188: Section E3 (Special) Step 4	**35**	**57.4**
RP188: Section E3 (Special) Step 4 IDEAS: Stage 5A Step 5.6.1	4	6.6
RP188: Section E3 (Special) Step 4 IDEAS: Stage 5C Step 5.17.1	1	1.6
RP188: Section E3 (Special) Step 5	4	6.6
RP188: Section E3 (Special) Step 6	2	3.3
RP188: Section E3 (Special) Step 6: IDEAS Stage 5A Step 5.1	1	1.6
RP188: Section E3 (Special) Step 6: IDEAS Stage 5A Step 5.6/5.6.1	3	4.9
RP188: Section E3 (Special) Step 6: IDEAS Stage 5B Step 5.14	1	1.6
Not specified	3	4.9

Four participants indicated that they have followed the procedure for Routine Monitoring, although the case description clearly indicated that it was a Special Monitoring case. Two participants jumped directly from Step 1 of the Special Monitoring procedure to the IDEAS Guidelines and stopped at Stage 5A, Step 5.6.1 (the results in terms of intake and committed effective dose are recorded, since dose < 1 mSv). Strictly speaking this process would be justified only if intake by wound, skin or decorporation therapy cannot be ruled out; but the case description did not give any hints about such possibilities. So it is not clear why these participants moved to IDEAS.

Also, four of the participants, who correctly indicate Step 4 of the Special Monitoring procedure as the termination step, give as an additional indication Stage 5A, Step 5.6.1 of IDEAS. One participant even indicated Step 4 of the Special Monitoring procedure and Step 5.17.1 of IDEAS stage 5C (advanced evaluation, adjustment of model parameters until a good fit is obtained). Actually Step 4 would not require to shift to IDEAS Guidelines, this should be done if the test of Step 6 is verified (the evaluated dose potentially exceeds the annual dose limit).

Four participants stop at Step 5 of the Special Monitoring procedure, which is actually only an intermediate step, because it just says to add additional special monitoring measurements and then move to Step 6. Four of the seven participants who indicate Step 6 moved to the IDEAS Guidelines Stage 5A. One of them moved to Stage 5B, Step 5.14 (simultaneous fitting of both the time of intake and the mixture of default absorption), although, strictly speaking, this stage should be reached only if the dose calculated in Stage 5A is ≥ 1 mSv.

As for the analysis according to ICRP OIR, 15 participants correctly stop the evaluation at Step 6 of the RP188 procedure for Special Monitoring (see Table 5-11). Most of the participants, however, proceed further and move to the IDEAS Guidelines, stopping at Stage 5A, Step 5.6.1. Also, in this case there are five participants who proceed to Stage 5B or beyond it, although this Stage should be reached only if the evaluated dose is ≥ 1 mSv. One participant stops at Stage 5B, Step 5.7, which is actually an intermediate step (Are there sufficient relevant data?), three participants stop at Stage 5B, step 5.11.3 (record of all parameters after performing a fit of the absorption types) and one proceeds further to Stage 5C, Step 5.15 of the IDEAS Guidelines (which is actually reached when the evaluated dose is greater than 6 mSv).

One possible reason for this spread of terminating steps may be the lack of clarity in RP188 on what to do when Step 6 of Section E3 is reached. Table E2 simply states that, if the annual dose limit is not exceeded, the assessor should document intake, dose and model parameter values. The text of RP188 however requires a test of the adequacy of the fit, inviting the assessor to follow the procedure as indicated in Section 6.3 of IDEAS. Therefore, even though Table E2 of RP188 indicates that the assessment should stop at Step 6 if the annual dose is not potentially exceeded, the requirement to check for the goodness of fit and, if the fit is rejected, to then proceed with the analysis, implicitly suggests the transition to the IDEAS Guidelines. This inconsistency between Table E2 and the text of RP188 should be resolved.

Table 5-11 : Terminating step in RP188 as reported for analysis according to OIR

Terminating Step	*Number of submissions*	*(%)*
RP188: Section E2 (Routine) Step 4	4	6.9
RP188: Section E2 (Routine) Step 6	3	5.2
RP188: Section E3 (Special) Step 1: IDEAS Stage 5B Step 5.11.3	1	1.7
RP188: Section E3 (Special) Step 3	2	3.4
RP188: Section E3 (Special) Step 4	4	6.9
RP188: Section E3 (Special) Step 4: IDEAS Stage 5C Step 5.15	1	1.7
RP188: Section E3 (Special) Step 5	2	3.4
RP188: Section E3 (Special) Step 6	**15**	**25.9**
RP188: Section E3 (Special) Step 6: IDEAS Stage 5A Step 5.1	1	1.7
RP188: Section E3 (Special) Step 6: IDEAS Stage 5A Step 5.6/5.6.1	18	31.0
RP188: Section E3 (Special) Step 6: IDEAS Stage 5B Step 5.7	1	1.7
RP188: Section E3 (Special) Step 6: IDEAS Stage 5B Step 5.11.3	3	5.2
RP188: Section E3 (Special) Step 6: IDEAS Stage 5C Step 5.15	1	1.7
Not specified	2	3.4

5.5 Errors performed by participants during the assessment

Typing errors or errors in the units: three of the submitted values were given in the wrong units (Sv instead of mSv, i.e. a factor 1000 lower); for one further value there was evidently an error in typing the value (a factor of 10 lower). In "real life" these errors of inattention may have unwanted consequences, especially when providing dose values in the wrong units; the implausibility of the result should be immediately acknowledged. Such types of trivial errors should be avoided in a quality assured procedure for the delivery of assessed dose reports to the costumer. A double-check of the values from independent evaluators could improve the quality of the delivered data.

6. Case 2

6.1 Case description

The event

Description of the working area

Production department of radiochemical plant.

Characteristics of work

Radiochemical production of I-125. Work has been performed in hermetically sealed boxes and chambers. Analysis of compounds, their calibration and packing are undertaken in hoods or at workplaces. Due to the high volatility of this radionuclide at all stages of production, leakage of a small quantity of I-125 into the air of the working areas is practically unavoidable

Reasons for monitoring; initiating event

Due to work procedures and potential exposure, routine monitoring by means of thyroid monitor has been established with a time period of approximately 90 d. The beginning of the monitoring period was 22/02/1986. Due to an unexpected exposure detected by the second monitoring result, two further special thyroid measurements were requested and performed on dates 02/09/1986 and 30/09/1986. After these special measurements the routine monitoring has been continued, performing measurements on 04/12/1986 and 28/03/1987. The provided thyroid monitoring data have to be considered as being collected in a sequential mode. Iteration of the dose assessment procedure for each exposure period must therefore be applied, considering, when applicable, the subsequent special thyroid measurements results in the same exposure period. The end of the monitoring period for transfer to another type of work was 01/04/1987.

Initial actions taken

None.

Additional information

Air monitoring

Monitoring of airborne radioactivity is used to control the level of contamination. However, such monitoring with filters is only capable of capturing the aerosol fraction of radioiodine, and is not adequate for the total estimation of contamination. No data available.

Chemical form

Not indicated. For intercomparison purposes consider the use of lung absorption type F.

Physical characteristics, particle size

Volatile fraction, not aerosol.

Nose swab, bronchial slime or similar

None

Non removable skin contamination

-

Wound site activity

-

Any intervention used (blocking, chelating, etc.)

None

Individual monitoring data

Organ activity measurement:

Thyroid activity measurements are available.

Whole body activity measurement

None.

Excretion monitoring data

Urine activity measurement

None.

Faeces activity measurement

None.

Personal Data

Sex

Female.

Age

Unknown

Weight

Unknown

Other comments relevant for dose estimation

The detection limit value for the monitoring device used can be assumed to be equal to 200 Bq ^{125}I in thyroid.
Evaluate the intake regimes, numbering them with increasing numbers. Consider a maximum of six intake regimes.

Table 6-1: Case 1: Thyroid measurement data

Type of sample	*Isotope*	*Date*	*Thyroid activity measurement (Bq)*	*Thyroid activity measurement percentage uncertainty (± 2 SD)*
ROUTINE	^{125}I	25/05/1986	3.29E+03	±14%
ROUTINE	^{125}I	13/08/1986	5.47E+04	±14%
SPECIAL	^{125}I	02/09/1986	3.33E+04	±14%
SPECIAL	^{125}I	30/09/1986	2.39E+04	±14%
ROUTINE	^{125}I	04/12/1986	1.03E+04	±14%
ROUTINE	^{125}I	28/03/1987	2.64E+03	±14%

6.2 ICIDOSE Reference Solution

In this paragraph the solution following the RP188 procedure is presented. The main hypothesis of inhalation of vapour has been adopted, following the physical characteristics indicated in the case description.

At the end of the paragraph alternative summary tables for the solution considering the inhalation of 5 μm AMAD aerosol are also provided.

First Monitoring result: 3290 Bq ^{125}I in thyroid

Table 6-2: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring

Step	Indication	Result	Justification
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Monitoring for ^{125}I is 90 d via thyroid monitoring. The 92 days from beginning of exposure to 1st monitoring is less than 90+14 days set as tolerance period	Go to Step 2
2	Check if the monitoring value is significant	Value M is > DL=200 Bq so M > DT = 100 Bq M also > Mc = 200 Bq as in table 3.10 IDEAS.	Go to Step 3
3	Standard dose assessment	SF= 1.263, m(T/2=46) = 0.114, I = 28860 Bq e(50) = 1.4 E-08 Sv/Bq ; E(50) = 0.404 mSv.	Go to Step 4

4	Check if the 97.5% confidence level of the assessed projected annual dose is greater than 5% of the annual dose limit	n = 4, SF= 1.263, therefore the value of $1/(4*SF^2) = 0.157$ mSv. So $E(50) > 1/(n.SF^2)$	Go to Step 5
5	Check if unexpected exposures can be excluded (i.e. if the exposure is expected)	NO unexpected exposures are considered to be present.	Go to Step 6
6	Check whether dose *potentially* exceeds annual dose limit	The curve of ISO at Fig. A17 page 48 of ISO27048 are related to 5 um AMAD : Use the equation E.5	Used T = 92 d. SF= 1.263 DIL_{min} = 3377 Bq. M= 3290 < DIL_{min} = 3377 Document: Path : Inhalation, Physical form: Elemental, Absorption type: F, Date of intake = 9/4/1986, Intake = **28.9 kBq** , e(50) = 1.4 E-08 Sv/Bq, E(50) = **0.404 mSv** . Final step : Table E.1 Step 6 End of evaluation. Go to Step 1 with result of the new monitoring period.

Second monitoring result: 54700 Bq ^{125}I in Thyroid

Table 6-3: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring

Step	Indication	Result	Justification
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Second monitoring at 80 days after the previous measurement	Go to Step 2
2	Check if the monitoring value is significant	Value M is > DL=200 Bq so M > DT = 100 Bq M also > Mc = 200 Bq as in table 3.10 IDEAS.	Calculation of contributions from previous intakes: Time period 13/8/86-9/4/86=126 d, m(126) = 0.0272, contribution = 785 Bq , SF = 1.263 ; SF^2 =1.596 ; P* SF^2 = 1253. M= 54700 Bq > P* SF^2= 1253. Go to Step 3.
3	Standard dose assessment	N = M-P = 53915 Bq , Date: 4/7/1986, m(T/2=40) = 0.127 I = 424528 Bq, E(50) = 5.94 mSv	Go to Step 4
4	Check if the 97.5% confidence level of the assessed projected annual dose is greater than 5% of the annual dose limit	n= 4 $1/(4* SF^2) = 0.157$ mSv so E(50) =5.94 mSv > $1/(n. SF^2)$	Go to Step 5

5	Check if unexpected exposures can be excluded (i.e. if the exposure is expected)	YES: measurement is **unexpected**.	Go to Step 5 of TABLE E.2

Table 6-4: adapted from RP188: Table E.2 Summary of ISO 27048:2011 procedure for Special Monitoring

Step	Indication	Result	Justification
5	Confirm assumption and findings related to exposure scenario	Other two values are available: 2/9/1986 M = **33300** Bq; 30/9/1986 M =**23900** Bq.	Having 3 thyroid measurements, data are considered to be sufficient (and no opportunity to collect further data). Go to Step 6
6	Check if the evaluated dose potentially exceeds the annual dose limit	As there is not the plot for elemental iodine, the equation E.8 of RP188 for the three measurements is used.	To calculate the time period between measurements and date of intake, t_i, to be used in eq. (E.8), not knowing the actual time of intake, the reference intake time of the second monitoring period (mid-point) has been used i.e. 4/7/1986. All values are **above** the $DIL_{minSM}(i)$ values. So the annual dose limit may potentially be exceeded. GO to IDEAS Guidelines Stage 4.

Table 6-5: adapted from IDEAS Guidelines (Version 2): Stage 4 + Stage 5

Step	Indication	Result	Justification
4.1	Pure inhalation	Evidence of pure inhalation	Go to Stage 5
5.1	Measured data	Three data are now available	Go to Step 5.2
5.2	Contributions from previous intakes	Evaluation of the contribution of the previous intake (first routine monitoring period) due to I = 28860 Bq at 9/4/1986	P(i) =785, 548, 332 Bq N values are : 53915, 32752, 23568 Bq Go to Step 5. 3
5.3	Assign *a priori* parameters		Inhalation, Vapour, F, mid of monitoring period (i.e. between 26/5/86 (beginning of current monitoring period and 12/8/86 one day before the first measurement of the second monitoring period (reference date = 4/7/1986). **Hypothesis: no further intakes will occur from 13/8/86 to 30/9/86, as the activities are always decreasing.**
5.4	Check on time of intake	The time of intake is **not** known.	Go to Stage 5B, Step 5.7

5.7	Sufficient relevant data?	Check the number of dose relevant data.	From Table 6.1 of IDEAS GLs page 59 for analogue I-131, in the column related to 1 mSv < D < 6 mSv, one obtains 2 thyroid + 2 urine data. We have 3 thyroid data: **data are considered to be sufficient** (and no opportunity to collect further data). Go to IDEAS Step 5.8
5.8	Check on time of intake	**No** : Time of intake is not known	Go to IDEAS Step 5.12
5.12	Assessment of dose by simultaneous fitting of both the time of intake and the absorption type	Consider always the absorption type F, and time of intake which spans between 26/5/1986 and 12/8/1986.	Fits to the data were performed assuming that intake had occurred on any day between 26/5/1986 and 12/8/1986. None of the fit was rejected, as P values were always greater than 0.81. So the **data are not informative** about the actual date of intake. Selected the mid-point of monitoring interval : 4/7/1986 P-value = 0.859 I = 410316 Bq E(50) = 5.74 mSv Go to IDEAS Step 5.12.1
5.12.1	Goodness of fit is acceptable?	As P-value = 0.859, the fit is accepted.	Go to Step 5.12.2
5.12.2	Dose < 6 mSv?	The E(50) is **less** than 6 mSv.	Go to Step 5.12.3
5.12.3	Record dose with all parameters	Record dose	Document: Path : Inhalation, Physical form: Elemental, Absorption type: F, Date of intake: 4/7/1986, Intake = **410 kBq,** e(50) = 1.4 E-08 Sv/Bq, E(50) = **5.74 mSv**, P-value = 0.859 Final step: IDEAS Step 5.12.3. End of evaluation. Go to Step 1 with result of the new monitoring period.

Third routine Monitoring result: 10300 Bq ^{125}I in thyroid

Table 6-6: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring

Step	Indication	Result	Justification
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Monitoring for ^{125}I is 90 d via thyroid monitoring. The 113 days from 13/8/1986 to 4/12/1986 is more than 90+14= 104 days, set as tolerance period.	**Anyway the monitoring has been considered to be routine.** Go to Step 2
2	Check if the monitoring value is significant	Value M=10300 Bq is > DL=200 Bq so M > DT = 100 Bq M also > Mc = 200 Bq as in Table 3.10 IDEAS. Evaluation of the previous contributions: m(239)= 3.62 E-03 28900*3.62 E-03=105 Bq (coming from 1st monitoring intake). m(153)= 0.0168 410300*0.0168 = 6893 Bq (coming from 2nd intake). Total contribution P = 105+6893= 6998 Bq SF = 1.263 SF^2 = 1.596 P*SF^2 = 11171 Bq P/SF^2= 4385 Bq P/SF^2=4385 Bq < M=10300 Bq < P*SF^2=11171 Bq	Value is significant. **No new intake** as the condition of eq. (4) of page 15 of ISO 27048:2011 is satisfied. (see paragraph 7.1.2.2). Document of the measurement. **No further dose assessment is needed.** **Intake set at 0.0 kBq,** **E(50) set at 0.0 mSv** Final step : Table E.1 Step 2 End of evaluation. Go to Step 1 with result of the new monitoring period.

Fourth routine Monitoring result: 2640 Bq ^{125}I in thyroid

Table 6-7: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring

Step	Indication	Result	Notes
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Monitoring for ^{125}I is 90 d via thyroid monitoring. The 114 days from 4/12/1986 to 28/3/1987 is more than 90+14= 104 days set as tolerance period.	**Anyway the monitoring has been considered to be routine.** Go to Step 2
2	Check if the monitoring value is significant	Value M is > DL=200 Bq so M > DT = 100 Bq M also > Mc = 200 Bq as in Table 3.10 IDEAS. Evaluation of the previous contributions: m(353) =4.72 E-04 28900*4.72 E-04 = 14 Bq (coming from 1st monitoring intake). m(267) =2.19 E-03 410300*2.19 E-03 = 898 Bq (coming from 2nd intake). Total contribution P = 912 Bq SF^2 = 1.596 P*SF^2= 1456	Value is significant. **New intake.** Go to Step 3

		As M = 2640 > P*SF^2= 1456 There is a **new intake**. N = M-P = 1728 Bq	
3	Standard dose assessment	Date: 30/1/1987; m(T/2=57) = 0.0935, I = 18480 Bq, e(50) = 1.4 E-08 Sv/Bq ; E(50) = 0.259 mSv.	Go to Step 4
4	Check if the 97.5% confidence level of the assessed projected annual dose is greater than 5% of the annual dose limit	The value of 1/(n* SF^2) = 0.157 mSv. So E(50) >1/(n.SF^2)	Go to Step 5
5	Check if unexpected exposures can be excluded (i.e. if the exposure is expected)	No unexpected exposures are considered to be present.	Go to Step 6
6	Check whether dose *potentially* exceeds annual dose limit	The curve of ISO at Fig. A17 page 48 of ISO 27048:2011 are related to aerosol of 5 um AMAD. Use the equation (E.5) at page 118 of RP188.	Used T = 114 d (28/3/1987 - 4/12/1986). m(T) = 0.0337; SF= 1.263 DIL_{min} = 2826. M = 2640 < DIL_{min} = 2826 Document: Path : Inhalation, Physical form: Elemental, Absorption type: F, Date of intake: 30/1/1987, Intake = **18.5 kBq**, e(50) = 1.4 E-08 Sv/Bq, E(50) = **0.259 mSv** . Final step : **Table E.1 Step 6** End of evaluation

Table 6-8: Final table: VAPOUR: parameters for each monitoring period

Monitoring period	Beginning	End	Type	Date	Intake (Bq)	E(50) (mSv)	RP188 step
1	22/02/1986	25/05/1986	Single	09/04/1986	2.89E+04	4.04E-01	Section E2 Routine Step 6
2	26/05/1986	13/08/1986	Single	04/07/1986	4.10E+05	5.74E+00	IDEAS Stage 5B, step 5.12.3
3	14/08/1986	04/12/1986	Single		0	0	Section E2 Routine Step 2
4	05/12/1986	28/03/1987	Single	30/01/1987	1.85E+04	2.59E-01	Section E2 Routine Step 6

Table 6-9 : Final table: VAPOUR: parameters for Total values

Total Intake (Bq)	4.58E+05
Used dose coefficient (Sv/Bq)	1.40E-08
Total CED (mSv)	6.41

Table 6-10: Final table: VAPOUR: Contributions of previous intakes to the subsequent measurements

		Intake #						
		1	2	3	4	5	Total contrib. (Bq)	Net value (Bq)
M	Bq	09/04/1986	04/07/1986					
2	54700	785					785	53915
3	33300	548					548	32752
4	23900	332					332	23568
5	10300	105	6893				6998	3302
6	2640	14	898				912	1728

Alternative solution applying RP188

Roughly half of the participants have made the initial assumption of inhalation of aerosol of 5 µm AMAD, contrary to the instructions given in the case description. The following three tables provide the solution derived by the straightforward application of the RP188 recommendations for the assumption of an inhalation of aerosol.

Table 6-11: Final table: AEROSOL 5 µm AMAD: parameters for each monitoring period

Monitoring period	Beginning	End	Type	Date	Intake (Bq)	E(50) (mSv)	RP188 step
1	22/02/1986	25/05/1986	Single	09/04/1986	5.41E+04	3.95E-01	Section E2 Routine Step 6
2	26/05/1986	13/08/1986	Single	04/07/1986	7.68E+05	5.61E+00	Section E3 Special Step 6
3	14/08/1986	04/12/1986	Single		0	0	Section E2 Routine Step 2
4	05/12/1986	28/03/1987	Single	30/01/1987	3.46E+04	2.53E-01	Section E2 Routine Step 6

In relation to the use of the graphical and table values reported in ISO 27048:2011 Figure A.17 and Table A.18 (page 48) the annual dose limit cannot potentially be exceeded, therefore there is no need to proceed towards IDEAS Guidelines. The evaluation for the second routine monitoring period stops after Step 6 of Special monitoring of Chapter E.3.

Table 6-12: Final table: AEROSOL 5 µm AMAD: parameters for Total values

Total Intake (Bq)	8.57E+05
Used dose coefficient (Sv/Bq)	7.3E-09
Total CED (mSv)	6.26

Table 6-13 : Final table: AEROSOL 5 µm AMAD: Contributions of previous intakes to the subsequent measurements

		Intake #						
		1	2	3	4	5	Total contrib. (Bq)	Net value (Bq)
M	Bq	09/04/1986	04/07/1986					
2	54700	785					785	53915
3	33300	552					552	32748
4	23900	333					333	23567
5	10300	104	6885				6989	3311
6	2640	14	899				913	1727

6.3 Overall measurements statistics for the participant solutions

6.3.1 Distributions of Intake values

In Figure 6-1 the distribution of the total intake values is reported.

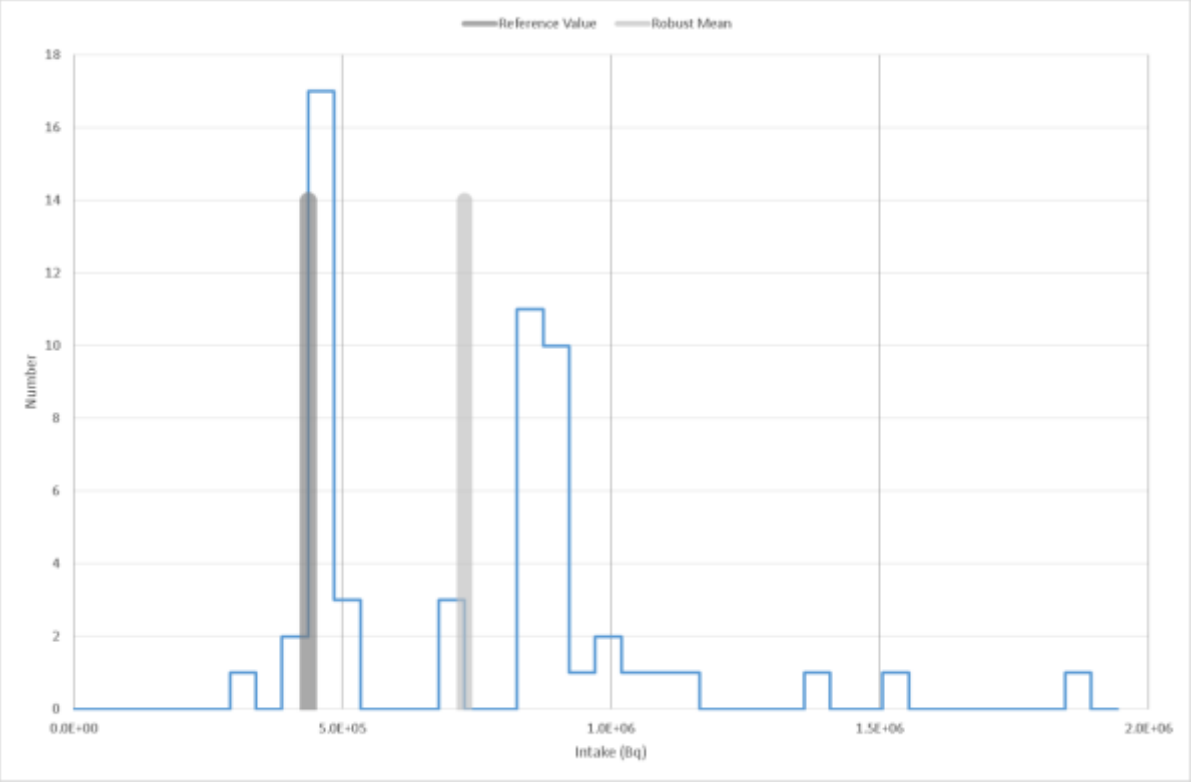


Figure 6-1 Distribution of total intake values

As can be seen the distribution presents two modes: one centred at around 4.6 E+05 Bq and a second one centred at around 8.6 E+05 Bq. These two modes are related, respectively, to the assumption of vapour and aerosol (5 μm AMAD) as the main hypothesis in the solution of the case. In the same figure both the ICIDOSE reference solution value and the robust mean are reported. As can be seen the first mode of the distribution is near the reference value, indicating that the participants have reached values that are not far from that reached following the RP188 methodology. The overall robust mean value instead is in between the values of the two modes.

The numerical data of the distribution are reported in Table 6-14.

Table 6-14: Overall statistics of solutions submitted for estimates of intake

Number of submissions	56
Quantity	Intake
Unit	Bq
Parameters excluding outliers	
GM	6.83 E+05
GSD	1.45
Number of outliers	1
Parameters including outliers	
Min	3.2 E+05
Max	1.85 E+06
Ratio Max/Min	5.78
Robust mean (RM)	7.25 E+05
Robust st. dev. (RSD)	2.77 E+05
RSD / RM (%)	38.1
ICIDOSE Reference value (Ref)	**4.58 E+05**
Ref/3	1.53 E+05
Ref*3	1.37 E+06
Number of data less than Ref/3	0
Number of data greater than Ref*3	3

The value of the geometric standard deviation equal to 1.45 determines the fact that only one value has been identified as outlier (PID 60).

The ratio between the maximum and minimum values equals 5.78, which is quite small.

The number of participants which provide values less than Ref/3 is null, so all results can be considered to be acceptable (no undue underestimation of intake has been observed).

Only three participants provide values that are above Ref*3 (PIDs: 11, 22 and 60).

The percentage RSD of 38.1% is comparable with the GSD value of 1.45, as ln(1.45) = 0.372.

In Figure 6-2 the histogram with the single values from each participant is reported. On the graph the intercept of the X axis on the Y axis is set at 4.58 E+05 Bq, i.e. to the ICIDOSE Reference value.

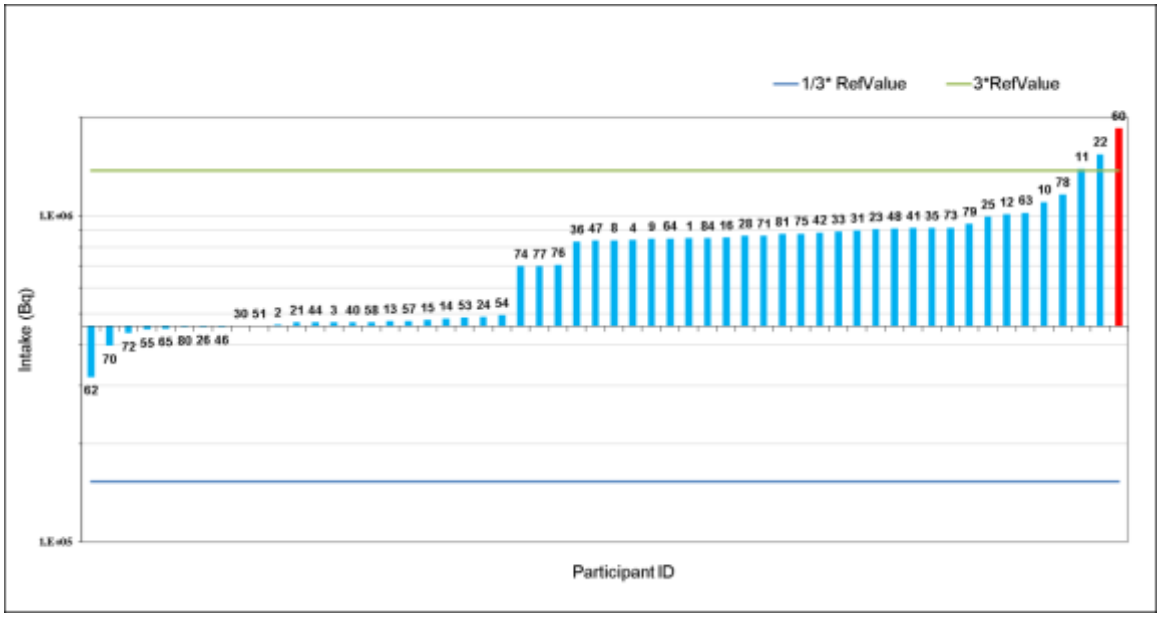


Figure 6-2: Histogram of total intake value. Outliers are indicated in red.

The value for PID 60 is the only identified outlier (reported in red).

As can be seen, a first subset of data (PIDs from 62 to 54) is positioned around the Ref value. Three transition values are present (PIDs 74, 77 and 76), then a second subset of values can be identified (from PID 36 to 78), and is mainly related to the aerosol approach. Finally, the three values that are above Ref*3 (1.37 E+06) are shown: i.e. PIDs: 11, 22 and 60, for which the value of intake can be considered unduly overestimated.

6.3.2 Distributions of E(50) values

In Figure 6-3 the distribution of the total E(50) values is reported.

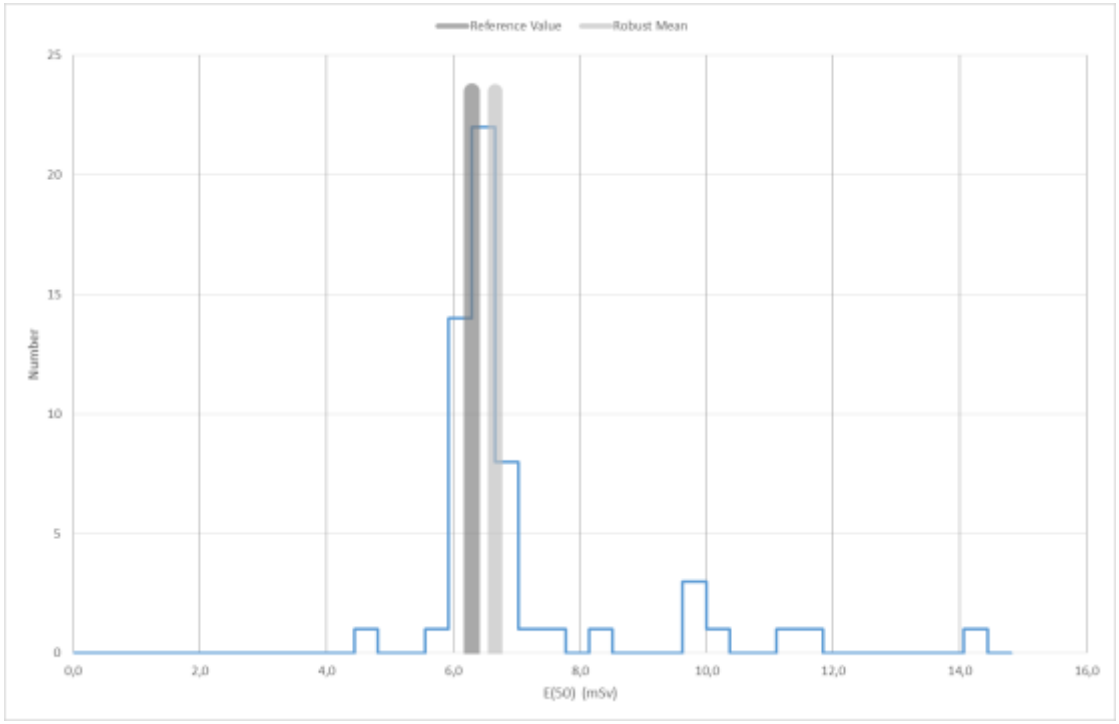


Figure 6-3 Distribution of total E(50) values

Except for some few data which exceed 10 mSv, and are mostly later evaluated as upper outliers, the distribution presents only 1 mode with the robust mean value not substantially different from the ICIDOSE reference value.

The overall statistical data of the distribution are reported in Table 6-15.

Table 6-15: Overall statistics of solutions submitted for estimates of committed effective dose E(50).

Number of submissions	56
Quantity	E(50)
Unit	mSv
Parameters excluding outliers	
GM	6.44
GSD	1.035
Number of outliers	12
Parameters including outliers	
Min	4.47
Max	14.10
Ratio Max/Min	3.15
Robust mean (RM)	6.56
Robust st. dev. (RSD)	0.41
RSD / RM (%)	6.3
ICIDOSE Reference value (Ref)	**6.41**
Ref/3	2.14
Ref*3	19.23
Number of data less than Ref/3	0
Number of data greater than Ref*3	0

As can be seen the very narrow value of the GSD (1.035) determines the identification of so many outliers (12). The GM value is practically coincident with the Ref value.

The ratio between the maximum and minimum values is only 3.15, confirming the narrowness of the distribution. Also the ratio RSD/RM of 0.0627 confirms that the distribution of values is very narrow. The RM value of 6.56 mSv is slightly different, but not substantially, from the Ref value of 6.41, calculated using the vapour approach.

No data are outside the interval of acceptable values of Ref/3 and Ref*3. So all results in terms of total E(50) are acceptable.

In Figure 6-4 the histogram with the single values of total E(50) from each participant is reported. In the graph the intercept of the X axis on the Y axis has been set at 6.41 mSv (Ref Value).

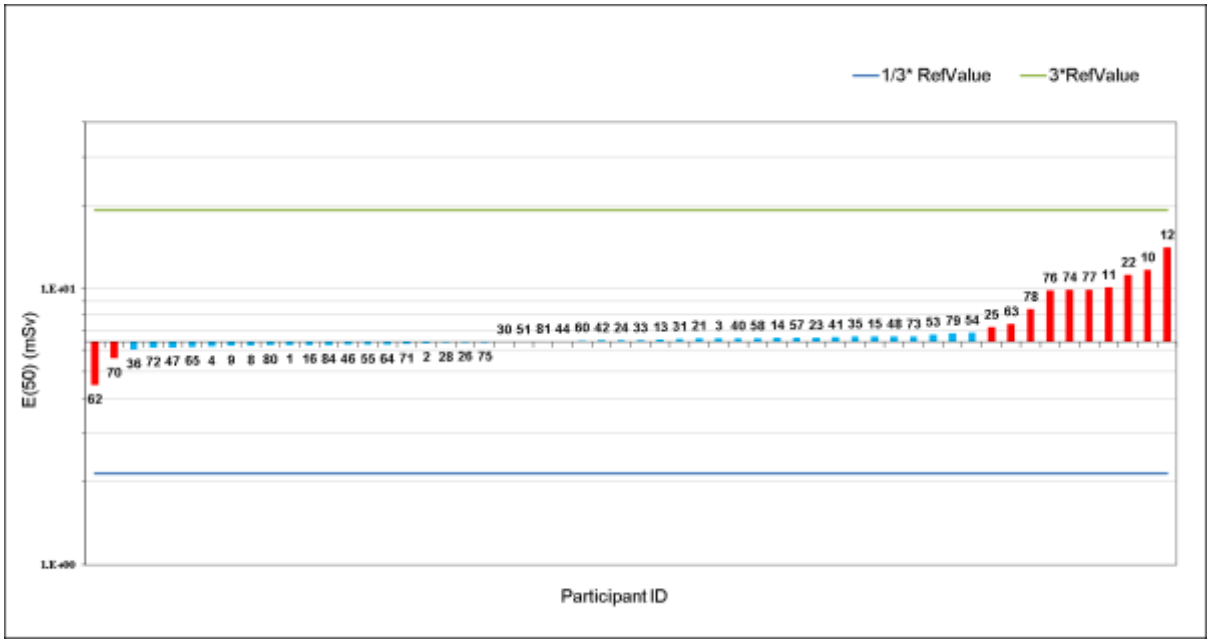


Figure 6-4: Histogram of total E(50) values. Outliers are indicated in red.

The values for PIDs 62 and 70 have been identified as lower outliers, while ten other PIDs (from 25 to 12) have been identified as upper outliers. Of the three PID values that have been identified to be greater than Ref*3 for intake, only PIDs 11 and 22 remain in the outlier band also for E(50). It is noted that PID 60 value for E(50) is well in the centre of the distribution, despite being an outlier for the reported value of intake. No values are outside the interval of acceptable E(50) i.e. [1/3*Ref;3*Ref]

As can be seen, the main part of the distribution (without the outliers) is in between the values of PIDs 36 and 54: respectively 6 mSv and 6.9 mSv, which is closely centred on the Ref value of 6.41 mSv.

Considering the discrepancies of intake values between vapour and aerosol approaches, and the substantial concordance of the E(50) values , it is possible to consider a compensating effect related to the used dose coefficient (see explanations at par. 6.4.1) which implies the robustness of the quantity "committed effective dose".

6.3.3 Scatter plot of values

Figure 6-5 shows the scatter plot between total E(50) values (in mSv) in respect of total evaluated Intake values (in Bq).

Each evaluation point is reported with a different shape and colour to indicate the declared accreditation of the participant: light blue lozenge for "Non-accredited centres", black circle for "Accredited centres". Furthermore the orange square is used for the reference Vapour solution and the red triangle for the reference Aerosol solution, both following RP188 methodology. The straight lines relate to the vapour and aerosol dose coefficients.

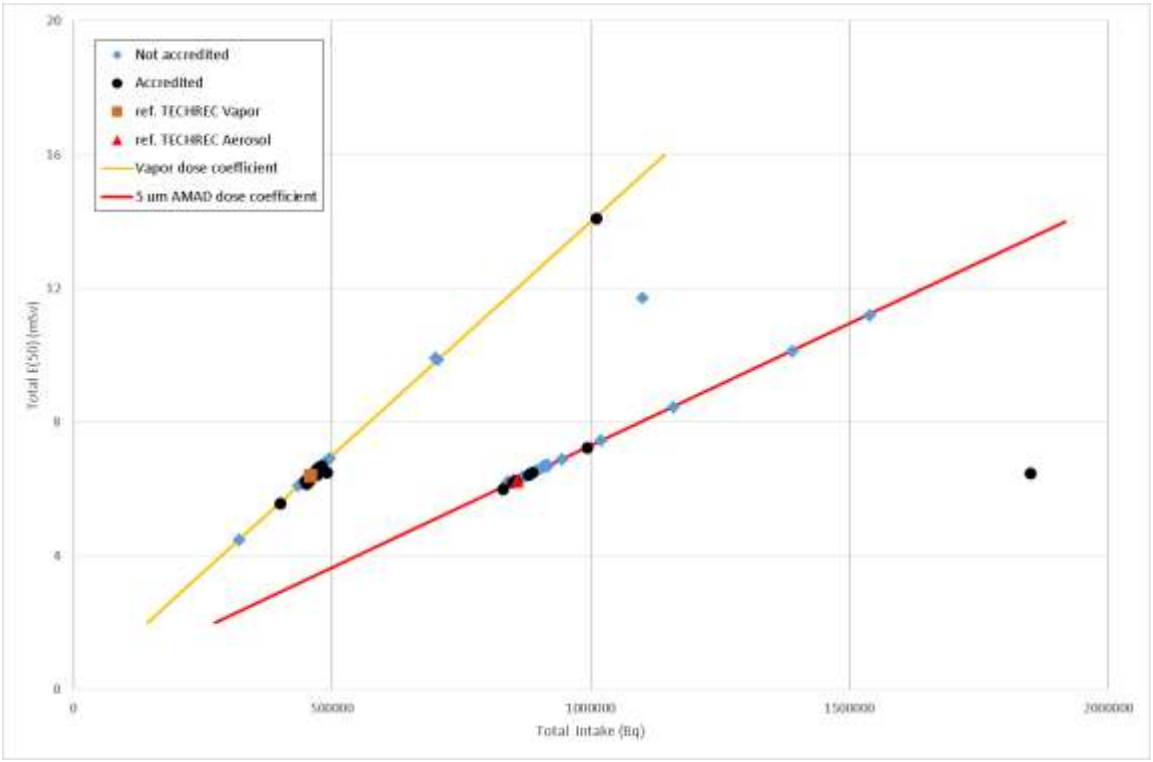


Figure 6-5 Scatter plot of Total E(50) versus total Intake values

As can be seen, the overwhelming majority of points are located on the two straight lines for the two main assumed dose coefficients. Only PID 10 [point (1.1 E+06; 11.7)] for "non-accredited", and PID 60 [point (1.85 E+06; 6.48)] for "accredited" participants present data that are not on the main straight lines (see paragraph 6.5.1).

6.4 Observations and discussion on selected aspects

Figure 6-6 presents, in graphical form, the hypotheses adopted during the reference solution of the case, as displayed as the time-line indicating monitoring periods, measurements and derived intakes.

Measurements are reported as M1 to M6 values, while intakes are reported as I1 to I4.

Measurements M2, M3 and M4 refer to the intake during the second monitoring period. Because the three measurements are not informative on the exact time for the supposed intake, the mid time period, i.e. 4/7/1986, has been adopted as the reference date of intake for the second monitoring period.

In the reference solution of the case it has been supposed that no other intakes occurred during the period between measurements M2 to M4. This is demonstrated with the actual decrease of the activity measured in thyroid.

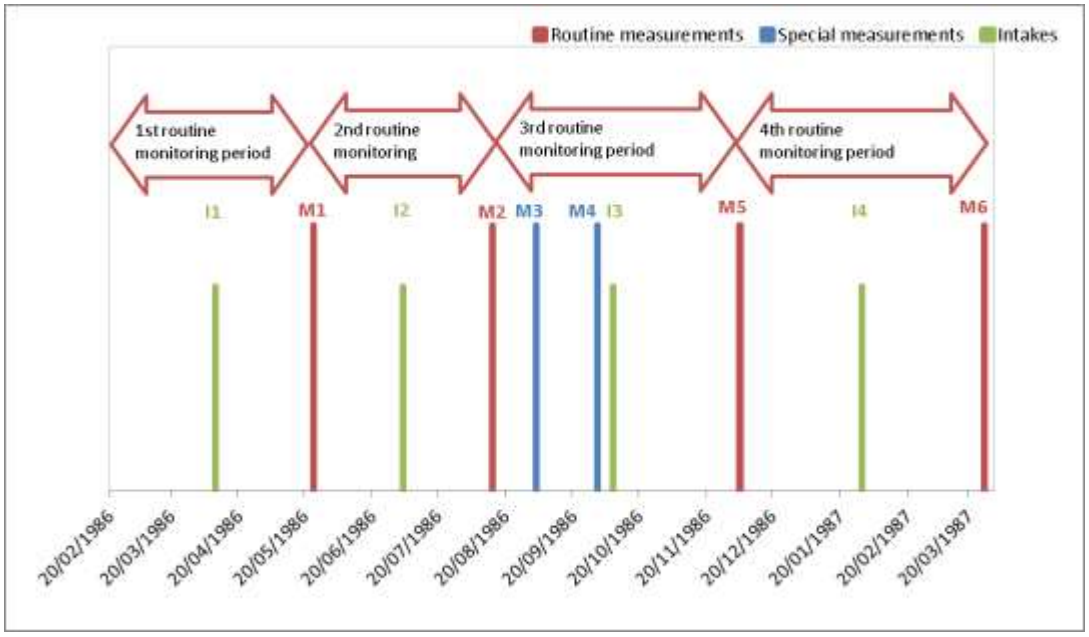


Figure 6-6: Time pattern of measurements and derived intakes.

For the third monitoring period there could be, theoretically, the possibility of a further intake, I3 (i.e. from time of M4 to time of M5). If that is the case then M5 should be above the contribution due to the first and second intake (set at 9/4/1986 and 4/7/1986 as already mentioned) i.e. $M > P*SF^2$, and the third intake can be similarly put to the mid-point of the third monitoring period. However, the analyses showed that no more intakes occurred as the M5 value is below $P*SF^2$ (I3 = 0). The M6 measurement is above the $P*SF^2$ value, with P evaluated on the basis of I1 and I2, both set at the respective mid-points of routine monitoring periods, thus indicating that a new intake I4 occurred between M5 and M6.

6.4.1 Vapour versus Aerosol

The main hypothesis considered in this section is related to the assumption of inhalation of vapour compared to the assumption of inhalation of aerosol.

Approximately half of the participants used vapour (29 participants) and half used aerosol (27 participants) as an "*a priori*" assumption.

The total committed effective dose for the reference solution does not change significantly: i.e. 6.26 mSv for aerosol, versus the Ref value of 6.41 mSv for vapour (ratio of 0.977); while the intake is practically doubled (factor of 1.87 = 8.57 E+05 / 4.58 E+05) for aerosol in respect to vapour.

These observations can be explained by comparison of the retention curves, and by comparison of the dose coefficients. The different retention curves are related to the percentages of inhaled material which deposit in the different regions of the human respiratory tract (HRTM). In Table 6-16 the percentages of deposition in HRTM are reported, with the total values that are eventually absorbed in the thyroid gland, from absorption after both inhalation and ingestion (after swallowing in ET2), i.e. from ET2 to AI. The ratio of the two percentages equal 0.535 (aerosol/vapour) and matches with the experimental average of the ratios of the retention values m(t), which is equal to 0.534: i.e. $\langle \frac{m(t)_A}{m(t)_V} \rangle$ (aerosol/vapour; the use of angular brackets "< >" refers to the operation of averaging), derived from MONDAL software (Ishigure 2004), as used for the reference solution.

Table 6-16: Percentages of deposition for ^{125}I vapour and 5 µm AMAD aerosol

Percentage deposited in the Region of the HRTM#	Vapour (SR-1) (%)	5 µm AMAD Aerosol (%)
ET1	10	33.85
ET2	40	39.91
BB	50	1.78
bb		1.10
AI		5.32
Total from ET2 to AI	90	48.11

= from ICRP 68,

To investigate the value of the ratio of the committed effective doses, the ratio of the calculated intakes (I_A/I_V) can be considered as the inverse of the indicated measurement ratio, i.e. 1.873, and then multiplied by the ratio of the e(50) values (i.e. 0.521) using the equation

$$\frac{E(50)_A}{E(50)_V} = \langle \frac{m(t)_V}{m(t)_A} \rangle \cdot \frac{e(50)_A}{e(50)_V} = \frac{I_A}{I_V} \cdot \frac{e(50)_A}{e(50)_V} = 1.873 \cdot 0.521$$

where the subscripts "A" and "V" represent aerosol and vapour, respectively. The ratio of the committed effective doses can be theoretically justified as being $\frac{E(50)_A}{E(50)_V} = 0.976$, which matches with the experimental ratio of Ref Values (0.977) reported above.

6.4.2 Acute versus chronic intakes

In the Table 6-17 the personal identification codes of participants (PIDs) are reported in relation to their main approach (vapour versus aerosol), and on the number and types of acute or chronic intakes.

Table 6-17: Personal identification codes (PIDs) related to the main adopted hypothesis and selection of acute (indicated with "A") or chronic (indicated with "C") intake patterns: e.g. the indication "1A+1C" means: one acute plus one chronic intake.

VAPOR (29 assessments)					
Acute		3A	4A		6A
PIDs		3, 10, 26, 30, 40, 44, 46, 55, 57, 58, 65, 70	13, 14, 15, 24, 54, 60, 62		74, 76, 77
Chronic	1A+1C	1A+2C	1A+3C	3C	1A+5C
PIDs	51	2	53, 72	80	12, 21
AEROSOL (27 assessments)					
Acute	2A	3A	4A	5A	6A
PIDs	48	1, 23, 78, 79, 84	9, 16, 25, 33, 41, 42, 63, 73, 75	35, 81	11
Chronic	1A+1C	1A+2C	4C / 1A+4C	1A+5C	2A+4C
PIDs	4, 8	64	36 / 28	22, 31, 71	47

As can be seen, the majority of assessments, both for the vapor and aerosol approaches, are related to the assumption of acute intake(s). The range of the numbers of intakes is from three to six for vapor, and from two to six for aerosol.

One participant (PID 48) considered only two acute intakes, 17 participants considered three acute intakes, and 16 considered four acute intakes. Only six participants consider five or six acute intakes.

The participants assuming six intakes appear to have misinterpreted the case description: they considered the two special measurements during the third routine monitoring period to be of routine type; therefore supposing additional intakes between the last routine and the first special measurement (M2 and M3), and between both special measurements (M3 and M4).

Similarly, the option of five intakes is considered to be erroneous, as one of the two special measurements has been considered to be of routine type.

Regarding the choice of four intakes, the participants have considered only the routine measurements, and for monitoring period 2 the other measurements have been used correctly, i.e. as special. As we have seen, the correct application of the RP188 recommendations determines that it is not appropriate to identify an intake for the third routine monitoring period, as the test on the previous contributions indicates that the intake value has to be set at zero.

The best evaluation is considered to imply only three acute intakes as the monitoring measurement (M5) is only due to the contribution of the two previous evaluated intakes. M6 is due to a new contribution in the last (fourth) routine monitoring period.

The assumptions of chronic intakes have been applied for solely chronic intakes (three or four chronic, as done by PIDs 80 and 36), or with a combination of one acute plus different numbers of chronic intakes, from one up to five; or, in case of PID47, two acute plus four chronic intakes.

The majority of the assessments indicate that an acute intake occurred in the second routine monitoring period, which also determines the majority of the total E(50) value.

As already reported, the combination of 1A+2C or 3C would be the best evaluation which includes chronic intakes, due to the identification of the intakes occurring during first, second and fourth routine monitoring period.

In the opposite extreme case of 2A+4C intakes, each measurement has been considered to be due to a specific intake. In the specific case of PID47 the two acute intakes have been erroneously set at the measurement dates of 2 and 30 September 1986, i.e. the dates of supplementary special measurements in the third routine monitoring period, in order to refine the date and value of the second routine intake.

Some participants (PIDs 4, 8 and 51) considered a continuous rate of intake, irrespective of measured values, during all the exposure period from 22/2/86 to 1/4/87: i.e. 403 days with a superimposed acute intake at 4/7/1986. Others, like PIDs 21 and 71, reported several periods but with an actual constant rate of intake, extrapolated on the basis of first measurement; while others have considered different rates of intakes in the different monitoring periods: PIDs 12, 31, 47.

6.4.3 *Comparison between accredited and non-accredited centres*

As mentioned in Section 6.3.3 in the comment to Figure 6-5, only PID10 for "non-accredited" [point (1.1 E+06; 11.7)] and PID60 [point (1.85 E+06; 6.48)] for "accredited" participants present data that are not on the main straight lines. No trend can be seen in relationship to the accreditation of the centre that performed the assessment, as data pertaining to both types can be found in each main adopted approach (vapour or aerosol).

The main statistical parameters for the comparison of the values of the two subsets are reported in Table 6-18.

Table 6-18: Parameters and PIDs related to Not Accredited and Accredited participants

	Non-Accredited (N = 35)				Accredited (N = 21)			
PIDs	2, 4, 8, 10, 11, 14, 21, 22, 23, 28, 31, 33, 35, 40, 41, 47, 48, 51, 53, 54, 57, 58, 62, 63, 64, 71, 72, 73, 74, 75, 76, 77, 78, 79, 80				1, 3, 9, 12, 13, 15, 16, 24, 25, 26, 30, 36, 42, 44, 46, 55, 60, 65, 70, 81, 84			
Total Intake								
	GM (kBq)	723	RM (kBq)	758	GM (kBq)	650	RM (kBq)	673
	GSD	1.46	RSD (kBq) (%)	280 (37%)	GSD	1.51	RSD (kBq)	270 (40%)

Total E(50)	GM (mSv)	7.05	RM (mSv)	6.75	GM (mSv)	6.61	RM (mSv)	6.38
	GSD	1.22	RSD (mSv) (%)	0.64 (9.5%)	GSD	1.20	RSD (mSv)	0.24 (3.8%)

Robust statistical parameters have been compared between data submitted by "Non-accredited" in respect to "Accredited" centres. While the percentage RSD remains unchanged for the values of total Intake (from 37% to 40%) from "Non-accredited" to "Accredited", the percentage RSD for the values of total E(50) reduces significantly, by a factor of 2.5, from 9.5% for "Non-accredited" to 3.8% for "Accredited" centres. As a visual evaluation in Figure 6-7, the comparison of the distributions of the E(50) results from the different types of centres has been reported. As can be seen the closeness of results is greater for "Accredited" centres. The improvement of the closeness of the results in the accredited group for total E(50) can be demonstrated by robust statistics. This is not supported by similar reduction of the GSD, which passes only from 1.22 to 1.20, so not changing the spread of values of total E(50).

No difference can be highlighted by t-test, at 5% level, one-tail, on log-modified data for the averages of values of total intake and total E(50) submitted by "Non-accredited" in respect to "Accredited" centres.

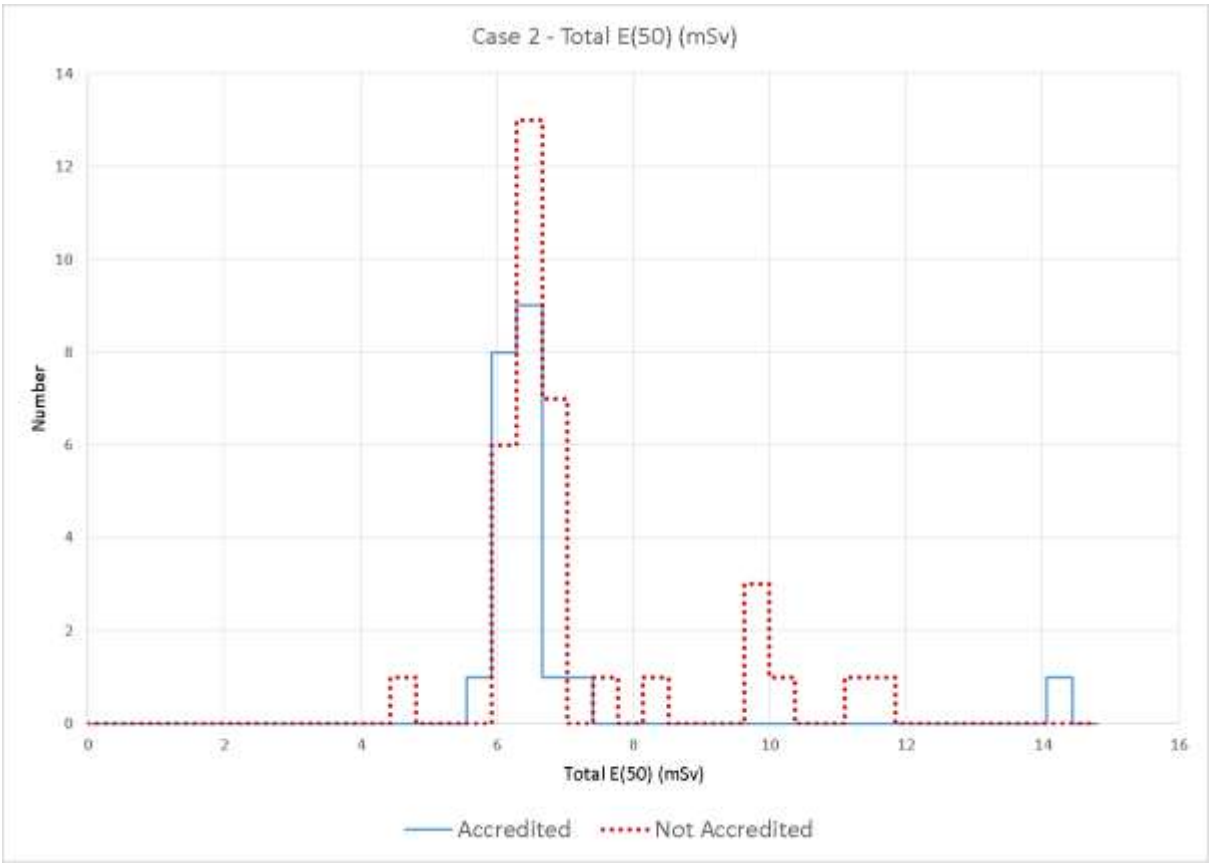


Figure 6-7: Comparison of distributions of E(50) values related to Accredited and Not Accredited participants

6.4.4 Step at which the analysis was terminated

Table 6-8 provides a summary of the procedural step, as defined in RP188 (and IDEAS, if appropriate), at which the reference solutions terminated.

The following four tables report the final step indicated by the identified participant, using the notation present in the Table 2 of the pdf smart file used for submission of results.

The first two tables (Table 6-19 and Table 6-20) are related to the vapour approach (both for first and second monitoring period), then the other two tables (Table 6-21 and Table 6-22) (always related to first and second monitoring period) are related to the aerosol approach.

In both tables the final steps in accordance to the ICIDOSE Reference solution are reported in bold, together with the related PIDs and number of submissions.

Table 6-19: Terminating step in RP188 as reported for VAPOUR choice for the FIRST monitoring period

Terminating Step	*PIDs*	*Number of submissions*
RP188: Section E2 (Routine) Step 4	14, 44, 53	3
RP188: Section E2 (Routine) Step 5	12, 15, 70	3
RP188: Section E2 (Routine) Step 6	**2, 3, 10, 13, 21, 24, 26, 30, 40, 44, 51, 55, 57, 58, 60, 62, 65, 72, 80**	**19**
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.12.3	74, 76, 77	3
Not specified	54	1

The majority i.e. 19/29 (66%) arrive correctly at the Section E2 (routine) Step 6, related to routine monitoring.

Table 6-20: Terminating step in RP188 as reported for VAPOUR choice for the SECOND monitoring period

Terminating Step	*PIDs*	*Number of submissions*
RP188: Section E2 (Routine) Step 5	12	1
RP188: Section E2 (Routine) Step 6	2, 40, 57, 58, 60	5
RP188: Section E3 (Special) Step 5	3, 21	2
RP188: Section E3 (Special) Step 6	24	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.7	65	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.11.2	15	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.11.3	80	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.12.3	**13, 26, 30, 46, 51, 53, 55, 72**	**8**
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.13	62	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5C Step 5.15	14, 70	2
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5C Step 5.15.1	10, 44, 74, 76, 77	5
Not specified	54	1

On the contrary to the first monitoring period, 0nly 8 participants out of 29 (26%) arrive correctly at the final step: IDEAS Stage 5B Step 5.12.3. This stage is related to recording E(50) in the period together with the related parameters, after having checked that E(50) is < 6 mSv (in the reference solution the value is 5.74 mSv). The path has been arrived at by the Step 5.12, where it is possible to try to find the optimum time of intake by varying it, when the actual time of intake is unknown, as in this case.

Due to it not being possible to use the table and graph reported in ISO 27048 for thyroid monitoring, the calculation approach based on the equation E.2 determines the need to go through the IDEAS approach.

Regarding the steps of IDEAS it can be stated:

- Step 5.7 is the request of additional data , Table 6.1 indicates for I-131 , 2 Thyroid + 2 Urine data. With three thyroid monitoring measurements the data has been considered to allow the assessment.
- Step 5.11.2 is related to the check if the E(50) assessed value is greater than 6 mSv, when the time of intake is known. This is not the case as the actual time of intake due to the second monitoring period is unknown and has to be determined by also taking the special monitoring results into account.

- Step 5.11.3 is the record of the E(50) (when the value is less than 6 mSv) but always when the time of intake is known.
- Step 5.13 is related to a mixture of absorption types (actually not applicable as all types for Iodine are considered to be F (fast) absorption) but always when the time of intake is known.
- Steps 5.15 or 5.15.1 are related to the check of the goodness of fit and recording the E(50) values and parameters. These final steps are not informative as they can be reached either when changing material or individual specific parameter values.

Table 6-21: Terminating step in RP188 as reported for AEROSOL choice for the FIRST monitoring period

Terminating Step	*PIDs*	*Number of submissions*
RP188: Section E2 (Routine) Step 4	4, 28, 31, 48	4
RP188: Section E2 (Routine) Step 5	41, 47, 73	3
RP188: Section E2 (Routine) Step 6	**1, 9, 16, 23, 25, 33, 36, 42, 64, 75, 78, 79, 81, 84**	**14**
Not specified	8, 11, 22, 35, 63, 71	6

In this case more than half of the participants (14/27; 52%), which use the Aerosol approach, correctly arrive at Section E2 (Routine) Step 6.

Table 6-22: Terminating step in RP188 as reported for AEROSOL choice for the SECOND monitoring period

Terminating Step	*PIDs*	*Number of submissions*
RP188: Section E2 (Routine) Step 4	28	1
RP188: Section E2 (Routine) Step 5	47, 73	2
RP188: Section E2 (Routine) Step 6	4, 31, 36, 81	4
RP188: Section E3 (Special) Step 6	**42, 75, 84**	**3**
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5A Step 5.2	33	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.7	25	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.12.3	1, 16	2
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5B Step 5.14	9, 41	2
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5C Step 5.15	48	1
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5C Step 5.15.1	64, 78, 79	3
RP188: Section E3 (Special) Step 6: IDEAS: Stage 5C Step 5.20.1	23	1
Not specified	8, 11, 22, 35, 63, 71	6

As can be seen for the final step of the RP188 procedures, a great variety of approaches have been performed by participants. As already mentioned, the correct evaluation does not require the need to go to the IDEAS steps because the visual evaluation, as can be done using table and figure of ISO 27048, indicate that, in the case of aerosol, the annual limit cannot have been potentially exceeded. So the RP188 evaluation stops at SECTION E3 (Special) Step 6. The choice performed by four participants related to Section E2 (Routine) Step 6 is not consistent with the nature of special monitoring for the second monitoring period.

No IDEAS steps are correct because the evocation of the IDEAS Guidelines is not needed, and especially not for stage 5C where material or individual specific parameter values can be modified.

Unfortunately only three participants out of 27, i.e. 11%, arrive eventually to the correct Section E3 (Special) Step 6 which corresponds to the ICIDOSE solution.

To summarize for the final step, indicated for the first and second monitoring period:

- For the first simple routine monitoring period 33/56 (60%) of evaluations terminated in the correct final step according to RP188 procedure.
- For the second routine monitoring period, in which an important intake occurred and in which some further special monitoring measurements are requested , a total of only 11 out of 56 (20%) of evaluations, correctly reached the respective RP188 (for aerosol) or IDEAS steps.
- Further effort should be put to improve the general application of the RP188 methodology.

6.4.5 Use of Software

In the following Table 6-23, the number of submissions related to the different software tools have been presented. As can be seen the most used software is IMBA (23 submissions, with different versions: from 4.0.42 to 4.1.61); then AIDE (4 submissions), MONDAL3 (3 submissions); DCAL and CALIN follow with only 1 submission each.

There is an apparent possible problem of rounding for dose coefficient in IMBA, in which the value of 1.37 x 10^{-8} Sv/Bq is calculated for the dose coefficient of 1.4 x 10^{-8} Sv/Bq for vapour, and 7.32 x 10^{-9} Sv/Bq versus 7.3 x 10^{-9} Sv/Bq for aerosol.

Table 6-23: Used software and number of submissions relative to the used software.

Used Software	*Number of submissions*
IMBA (from ver. 4.0.42 to 4.1.61)	23
AIDE (#)	4
MONDAL3	3
DCAL	1
CALIN	1
None (includes the reported use of MS Excel)	26

(#) = One participant, PID 42, indicated to have used both IMBA, AIDE and Excel, and has been included in the statistics for each.

"Excel" has been explicitly indicated by three participants, even if this is also considered the normal way to record a calculation as "by hand". Therefore, the majority of the participants which have indicated "No" might have used a spreadsheet to perform calculations, as well as those who have indicated "Excel" as software.

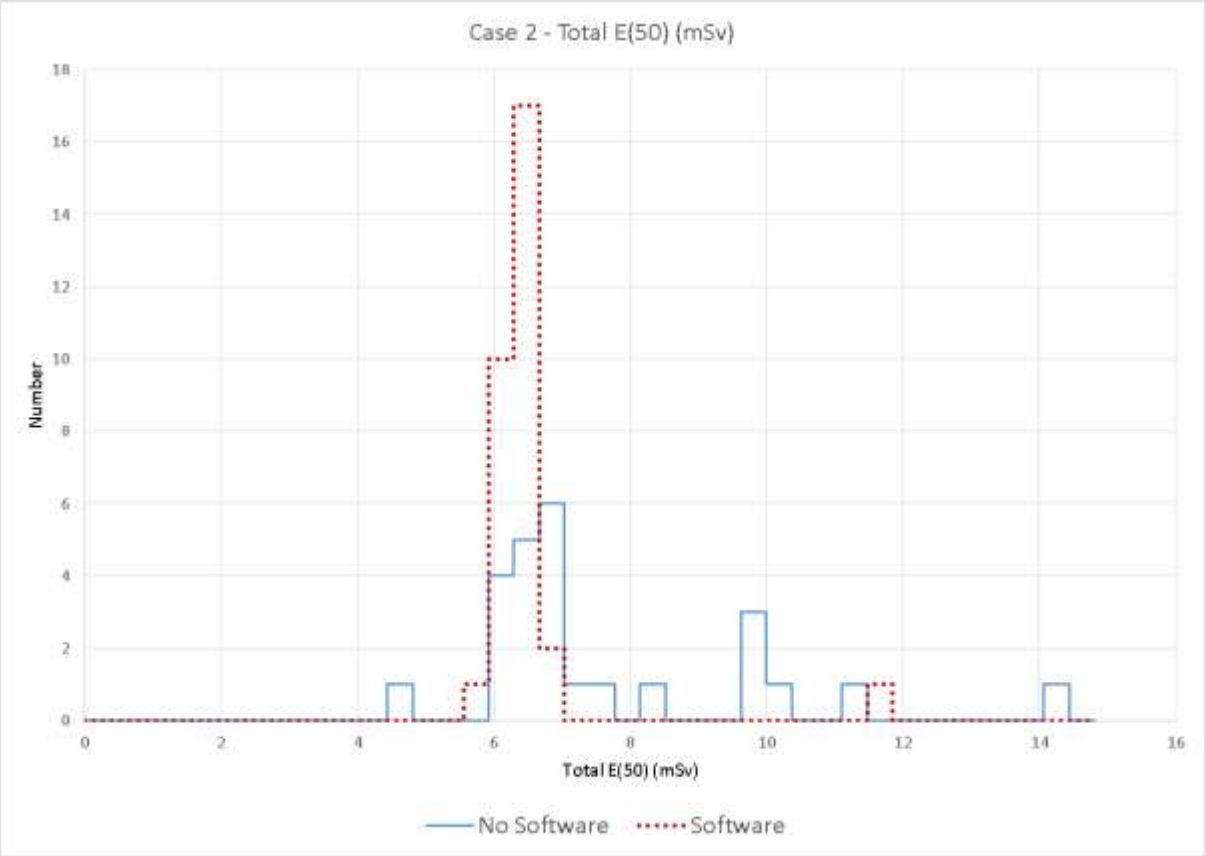


Figure 6-8: Comparison of distributions of E(50) values related to participants that have used or not used software tools

Figure 6-8 displays the comparison of the distribution of the values of total E(50) between participants that have used software tools and those that have not. In the "No Software" category the three participants who have indicated "Excel" have also been included.

As can be seen, the distribution of the results is narrower for values from participants who have used software tools.

6.5 Errors performed by participants during the assessment

In this paragraph two main sources of errors have been considered: the first is related to "Reporting Errors" (e.g. transcription errors, or related to quantities and units), while other errors are related to the application of RP188, which are considered as "Methods Errors".

6.5.1 Reporting errors

Participant PID 8 expressed the first routine monitoring E(50) value in correct units, i.e. in mSv, as requested. For the other acute exposure he adopted a value that is expressed in "Sv" units instead of "mSv". The total E(50) value is also erroneously reported as "Sv". The participant confirmed the correction to the units, which were then used in the analyses of the results.

In the specific record of Table 3 for the "Used dose coefficient", participant PID 81 reported the value related to vapour; however, the actual values of the dose coefficient, as implied from the calculations for the five acute monitoring periods, are related to aerosol.

Participant PID 28 did not report the value of the used dose coefficient. From the ratio between the total E(50) and the total intake the participant has been placed inside the group using the "aerosol" approach. PID 36 reported "as at software" and, using the same ratio, has been put inside the same "aerosol" approach group.

PID 81 reported, for the used dose coefficient, the value related to the "vapour" approach. Actually the ratio of the total E(50) and the total intake determines a value that indicates that this participant should be assigned to the "aerosol" approach group.

As a trivial reporting error, PID 22 and PID 63 erroneously reported the dose coefficient "7.03E-09" instead of the actually used value for "aerosol" approach: i.e. 7.3E-09.

For PID 10 the incorrect use of the dose coefficient for the second monitoring period, of 1.04E-08 (instead of 1.4E-08 Sv/Bq), which may be from a trivial transcription error, implies the determination of a total value of dose coefficient of 1.06E-08 Sv/Bq; and thence the displacement of the point in Figure 6-5 to be under the line related to the vapour dose coefficient, even if the declared dose coefficient is 1.4E-08 Sv/Bq.

For PID 60 an error of summation leads the participant to declare a total intake of 1.85E+06 Bq instead of the value of 4.88E+05 Bq, derived from the correct summation of the four reported intakes. In this case the used dose coefficient is 6.48 E-03/1.85 E+06 = 3.5 E-09 Sv/Bq, even though the participant indicated the value 1.37E-08 Sv/Bq. Using the correct summing value for the total intake, the dose coefficient can be calculated to be 6.48 E-03/4.88 E+05 = 1.33 E-08 Sv/Bq, a value nearer to the correct value of 1.4E-08 Sv/Bq to be used for vapour approach.

Such types of trivial errors should be avoided in a quality assured procedure for the delivery of assessed dose reports to the costumer. A double-check of the values from independent evaluators could improve the quality of the delivered data.

6.5.2 Indication of the final steps (not reported) (Methods Errors)

Contrary to the principal aim of the intercomparison exercise, which is the test on the applicability of the RP188 recommendations, the participants with the PIDs reported in Table 6-24 have not indicated any final steps of any monitoring periods.

Table 6-24: PID codes for participants which do not indicate the final step in any monitoring periods

Main hypothesis VAPOUR	Main hypothesis AEROSOL
54	8, 11, 22, 35, 63, 71

The percentage is not so low, as this represents 12.5% of all submissions. These PIDs participants missed the principal aim of the intercomparison.

It would be important to understand if they actually have used the recommendations or their own procedures of dose assessment.

6.5.3 Indication of the previous contributions (not reported) (Methods Errors)

As the secondary aim of the intercomparison for Case 2 is the calculation of the contribution to measurements from previous, already evaluated intakes, the first selection is of those participants which have not reported any contributions at all; as shown in Table 6-25.

Table 6-25: PIDs of participants which missed to report any contributions.

Main hypothesis VAPOUR	Main hypothesis AEROSOL
none	4, 8, 47

These participants have not filled in the "Table 4: Evaluating of the contribution of the previous intakes" of the smart pdf file to submit results of Case 2.

The RP188 recommendations, assuming the ISO 27048 approach, indicates the need to test for contributions from previous intakes and, if passed, then permits the reduction of the measured value to take into account the previously evaluated intakes. No information is thus collected for these three PIDs.

In the Table 4 of the smart pdf file, participant PID 11 indicated the notation "< DL" for all contributions from the first acute intake. Considering the reference solution as related to the aerosol approach (reported at the end of the section 6.2), the notation can be considered correct for the contribution to the fifth and the sixth measurements, but not for the contribution to the second, third and fourth, as they are greater than 200 Bq. Therefore in this case it is not possible to verify which values have been subtracted during the evaluation.

6.5.4 Error on reporting the contribution from second intake on the Special measurements M3 and M4 (related to the use of Special monitoring data)

As presented in the basic hypothesis for the solution of the case, it is not necessary to calculate the contribution to M3 and M4 as they are related to the same second intake, as its magnitude determines the request for further special measurements.

The following participants, identified with their PIDs, performed the error of putting a contribution due to the second intake onto the third and fourth special monitoring measurements (33300 and 22100 Bq).

The calculation of contributions from previous intakes is needed when a new intake is suspected and not when the previous intake has to be confirmed, as requested in the case of second routine monitoring by the further two special measurements. However, the calculation of the contribution of the second intake on the fifth and sixth measurements is needed to properly assess the intake in the third and fourth routine monitoring periods.

Table 6-26: Participant PIDs which indicate contribution (erroneously) or do not indicate contribution (correctly) from the 2nd intake to the 3rd and 4th special monitoring measurements.

Main hypothesis VAPOUR		Main hypothesis AEROSOL	
Indicate contribution (erroneous)	Do not indicate contribution (correct)	Indicate contribution (erroneous)	Do not indicate contribution (correct)
2, 3, 12, 14, 15, 21, 24, 26, 40, 44, 51, 53, 54, 57, 58, 60, 62, 65, 72, 74, 76, 77, 80	10, 13, 30, 46, 55, 70,	1, 11, 22, 23, 25, 28, 31, 33, 35, 36, 41, 48, 63, 71, 73, 75, 79, 81, 84	9, 16, 42, 64, 78
23 PIDs	6 PIDs	19 PIDs	5 PIDs

As already mentioned, PIDs 4, 8 and 47 did not indicate anything.
As indicated in

Table 6-26 only 11 out 56 PIDs (20%) correctly do not indicate the contribution of the second intake on the special monitoring measurements related to the same routine monitoring period.

*6.5.5 Calculation of the previous contribution and correct application of the M < P*SF² test (Methods Errors) for the third routine monitoring period*

The final step of the first and second routine monitoring period has already been considered in paragraph 6.4.4. Regarding the third routine monitoring period, the application of the RP188 reference procedure , both for vapour and aerosol approach, determines the calculation of an intake value to be set to zero, as the measurement M is < $P.SF^2$, when considering the P value calculated on the basis of the two already evaluated intakes in routine monitoring one and two.

The following PIDs are judged to have either performed correctly (i.e. setting the third routine monitoring period intake equal to zero due to M < $P.SF^2$), or not correctly (i.e. setting the intake of the third period (13/8/86-4/12/86) at a value different from zero (0)) .

Table 6-27: PIDs related to the choice of setting the 3rd routine monitoring period intake equal to zero.

Main hypothesis VAPOUR		Main hypothesis AEROSOL	
Set at a value different from zero (incorrect)	Set at zero (correct)	Set at a value different from zero (incorrect)	Set at zero (correct)
10, 12, 13, 14, 15, 21, 24, 51, 53, 54, 57. 60, 62, 74, 76, 77	2, 3, 26, 30, 40, 44, 46, 55, 58, 65, 70, 72, 80	4, 8, 9, 11, 23, 25, 28, 31, 33, 35, 36, 41, 42, 47, 63, 71, 73, 75, 81	1, 16, 48, 64, 78, 79, 84
16 PIDs	13 PIDs	19 PIDs	7 PIDs

Not reported: PID22

As can be seen from Table 6-27 only 20 participants out of a total of 56 (i.e. 36%) correctly performed the test indicated by RP188 and set the third intake to zero. This percentage is low.

As a justification to participants, it can be stated that in the RP188 recommendations it is not explicitly indicated how to perform the test between P and M, but that the ISO 27048 standard should be consulted.

It is suggested that the paragraph relative to the indicated test (ISO 27048, 7.1.2.2) is included in any revision of the RP188 text.

6.5.6 Reported date for the calculation of the contribution from a previous chronic intake for those that have used at least one chronic intake

In these last two paragraphs the date set for the calculation of the contributions both from chronic and acute intakes will be investigated. This will be done on the basis of the reported time patterns of intake (acute versus chronic) and reported dates on the top of Table 4 of the smart pdf file for submission of results.

First of all, the date set for the calculation of the contribution from a chronic intake has been evaluated for those which have used at least one chronic intake to solve the case.

Table 6-28: PIDs of participants which indicate the specified date for the calculation of the contribution of a previous chronic intake between those which have used at least one chronic intake.

Main Hypoteses *Set date*	*PID#* *Main hypothesis VAPOUR*	*PID #* *Main hypothesis AEROSOL*	*Number of submissions*
Not known :	51		1
Beginning of monitoring period		28	1
Mid-point of monitoring period	2, 53, 72	64	4
End of monitoring period	12		1
No indications	21, 80	4, 8, 22, 31, 36, 47, 71	9

As can be seen from the Table 6-28, the majority of participants (9 out of 16) give no indications in Table 4 of the smart pdf file of results.

Four reported the date of the mid-point of the respective monitoring period.

One (PID 51) reported a date (8/3/1986) not connected with the dates of the reported monitoring period (beginning (22/2/1986), mid-point (11/9/1986) or end (1/4/1987)).

Two PIDs reported the dates at the beginning (PID 28) or of the end (PID 12) of the respective monitoring periods.

The reference solution, using the acute mid-point procedure, has been compared with that provided by PID 80: i.e. with three chronic rate intakes respectively in first, second and fourth routine monitoring periods, both following the RP188 procedure. The outcome of the comparison is positive in the sense that the partial and total intake values are absolutely comparable, as well as the components of the contributions reported in Table 4 of pdf of results.

6.5.7 Reported date for the calculation of the contribution from a previous acute intake for those that have used at least one acute intake

This paragraph considers the selection of the date of intake for the calculation of the contribution from a previous acute intake, from those participants which have used at least one acute intake.

As can be seen from the Table 6-29 the majority of the participants, i.e. 32/47 (68 %), selected the mid-point date to calculate the contribution to future measurements. Only two participants reported the date of the beginning of the monitoring period, and 13 participants (28%) have selected a date that is not connected to the beginning, mid-point or end of the monitoring period.

The choice by PID 10, for both of the second and third routine monitoring periods (from 26/5/1986 to 4/12/1986), of putting the intake date at the beginning of monitoring period (26/5/1986) (instead of the date of the mid-point of the second routine monitoring period 4/7/1986) determines an overestimation of the intake by a factor 2.6 (1.07 E+06 Bq versus 4.1 E+05 Bq). This is due to the use of the three measurements M2, M3 and M4 but related to an intake date that is 39 days before the considered reference time of intake.

Table 6-29: Date for the calculation of the contribution of a previous acute intake: between those which have used one to 6 acute intakes.

Main Hypoteses Set date	*Number of used acute intake(s)*	*PID# Main hypothesis VAPOUR*	*PID # Main hypothesis AEROSOL*	*Number of submissions*
Not known	1		22*	1
	2		48	1
	3	55, 57, 65	78,	4
	4	14, 15, 54, 60, 62	25, 63	7
Beginning of monitoring period	1	12		1
	3	10		1
Mid-point of monitoring period	1	21	28, 64, 71	4
	3	3, 26, 30, 40, 44, 46, 57, 58, 70	1, 23, 79, 84,	13
	4	13, 24	9, 16, 33, 41, 42, 73, 75	9
	5		35, 81	2
	6	74, 76, 77	11	4

* = (trivial error 7/4/86 for 4/7/86?)

For PID 12 the M2 measurement has been evaluated considering an acute intake at the beginning of the monitoring period: i.e. 79 days before (13/8/86 minus 26/5/86). The estimation of the intake for vapour leads to a value of 8.68 E+05 Bq (m(t) = 6.3 E-02 Bq thyroid/Bq intake). The participant has provided a value that is approximately one order of magnitude less than that, i.e. 8.38 E+04 Bq; a value comparable to that evaluated by PID 10 would be expected, e.g. approximately double that of the reference value, at around 8 E+05 Bq. Therefore it is not clear if the underestimated intake, by one order of magnitude, is attributable to a trivial transcription error.

7. Case 3

7.1 Case description

The Event

Description of the working area

Solid radioactive waste storage and processing facility associated with a civil nuclear site.

Characteristics of work

The nature of the operations in the facility include decontamination of contaminated components, waste packaging and inspection of waste containers. The principal contaminants in the facility are plutonium, americium and uranium; with less significant contributions from fission and activation products. The relative radionuclide content can vary significantly with each item and operation. The worker started work in this facility on 1st February 2014.

Reasons for monitoring; initiating event

The worker was placed on a routine bioassay confirmatory monitoring programme for reassurance that significant exposures (> 6 mSv per annum) were not missed by the primary assessment monitoring programme by Personal Air Sampler. The sampling programme included annual urine sampling for uranium analysis by alpha spectroscopy. The worker provided a first routine urine sample in May 2014; this sample produced a result greater than the pre-defined Investigation Level of 3 mBq/day (summed activity from ^{234}U, ^{235}U and ^{238}U).

Initial actions taken

Repeat special urine samples were provided.

Additional information

Air monitoring

The work areas are subject to continuous workplace air monitoring (SAS) and workers are required to wear Personal Air Samplers (PAS) for all entries to controlled areas. There was no evidence of any acute or chronic air activity from either PAS or SAS.

Chemical form

Unknown: however, the facility can contain uranium contaminants in a range of chemical forms; materials with default (ICRP66) lung absorptions of Types F, M and S are feasible. The default a priori assumption for the monitoring programme is a lung absorption of **TYPE S**.

Physical characteristics, particle size

Particle size is unknown; however, the facility does not include any processes that would preferentially generate aerosols of any specific dimensions.

The default a priori assumption for the monitoring programme is an **AMAD of 5 micrometers**.

The facility can contain uranic contaminants in a wide range of enrichments: including depleted uranium, natural, low and highly enriched uranium.

There is no default a priori assumption of radionuclide mix.

Nose swab, bronchial slime or similar

None

Non removable skin contamination

No records of any skin contamination event.

Wound site activity

No records of any wounding event.

Any intervention used (blocking, chelating, etc.)

None

Individual monitoring data

Organ activity measurement:

None.

Whole body activity measurement

None.

Excretion monitoring data

Urine activity concentration measurements

Urine sample measurement data is provided in Table 7-1.

Urine samples were collected in 1.5 Litre bottles, with one bottle per sample. The samples were collected over several days, as indicated in the data. There is no further detailed information on the timings of when voidings were provided. There are two results with a sample date of 8/7/2014, one with a sample collection period of 3 days and one with a period of 1 day: it might be considered that the first represents sample collected sometime over the 3-day period ending 8/7/14, and the second collected only on the date of 8/7/14. For the purpose of this intercomparison assume that the measurement result represents the mean measured excretion rate on the date specified.

Each sample is analysed for ^{234}U, ^{235}U and ^{238}U content. Analysis is by alpha-spectroscopy. Quoted uncertainties are 2 standard deviations of measurement uncertainty. Sample results have been normalised to 1.4 litres volume, and by tracer yield. Volume normalisation factors are typically < +/- 1.1; tracer correction factors are typically 1.25, with tracer uncertainty of +/- 5% (combined relative uncertainty for measurement and calibration).

Typical *a priori* Detection Limit for this technique is approximately equivalent to 1 mBq / day.

The estimated *a posteriori* Decision Threshold values are included in Table 7-1, such that the data might be used numerically or as 'less than Decision Threshold' values.

Faeces activity measurement

None.

Personal Data

Sex

Male.

Age

Date of Birth: 1960

Weight

109 kg (as at 2014)

Other comments relevant for dose estimation

There are no records of any previous exposure to uranium. Expected annual individual internal exposures for the work area are < 1 mSv Committed Effective Dose. Expected annual individual external exposures for the work area are < 1 mSv Effective Dose. Bioassay urine records for all co-workers over same time period show no results greater than the Decision Thresholds for the measurements. The facility is located in the UK.

Table 7-1 : Case 3 urine measurement data

Type of sample	*Isotope*	*Date*	*Sample collection period (days)*	*Result (normalized to 24h)*	*+/- (2 sd)*	*units*	*Decision Threshold*
Confirmatory	U234	11/05/2014	9	2.83	0.7	mBq/d	0.82
	U235	11/05/2014	9	0.15	0.16	mBq/d	0.19
	U238	11/05/2014	9	2.26	0.63	mBq/d	0.73
SPECIAL	U234	08/06/2014	9	5.47	1.05	mBq/d	1.22
	U235	08/06/2014	9	0.35	0.27	mBq/d	0.31
	U238	08/06/2014	9	3.15	0.8	mBq/d	0.93
SPECIAL	U234	03/07/2014	7	4.69	0.56	mBq/d	0.65
	U235	03/07/2014	7	0.08	0.08	mBq/d	0.09
	U238	03/07/2014	7	3.36	0.47	mBq/d	0.55
SPECIAL	U234	06/07/2014	3	2.29	0.44	mBq/d	0.51
	U235	06/07/2014	3	0.11	0.1	mBq/d	0.12
	U238	06/07/2014	3	1.4	0.35	mBq/d	0.41
SPECIAL	U234	08/07/2014	3	4.25	0.61	mBq/d	0.71
	U235	08/07/2014	3	0.11	0.1	mBq/d	0.12
	U238	08/07/2014	3	2.33	0.45	mBq/d	0.52
SPECIAL	U234	08/07/2014	1	6.09	0.64	mBq/d	0.75
	U235	08/07/2014	1	0.3	0.14	mBq/d	0.16
	U238	08/07/2014	1	4.27	0.54	mBq/d	0.63
SPECIAL	U234	09/07/2014	1	3.25	0.52	mBq/d	0.61
	U235	09/07/2014	1	0.06	0.07	mBq/d	0.08
	U238	09/07/2014	1	1.75	0.38	mBq/d	0.44

7.2 ICIDOSE Reference Solution

The ICIDOSE Reference Solution is presented below in table form, Table 7-2 to Table 7-5; and is a facsimile of the format used to summarise the procedural steps within RP188 Chapters E2 and E3, and IDEAS.

Table 7-2: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring.

Step	Indication	Result	Justification
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	Annual confirmatory monitoring programme does not comply with ISO20553: **Go to Special Monitoring, Table E.2 – Step 1**	Neither RP188 nor ISO27048 are explicit about treatment of results from confirmatory monitoring; however, results are above the Investigation Level specified in the Case Description, which implies Special Monitoring is required

Table 7-3: adapted from RP188: Table E.2 Summary of ISO 27048:2011 procedure for Special Monitoring.

Step	Indication	Result	Justification
1	Check if an intake via wound, intact skin or influenced by decorporation therapy can be ruled out	No evidence of wound. **Go to Step 2**	The solution proceeds on the basis of 'no evidence' to indicate a wound.
2	Check if the measured value is significant	All measured values for ^{234}U & ^{238}U and 2 data for ^{235}U are above Decision Threshold. No contributions from past intakes. **Go to Step 3**	ISO27048 states that natural backgrounds should not be subtracted from measurement data when comparing to Critical Value: but this is not relevant for special assessments; and there is no indication to subtract background when comparing to Decision Threshold. All data reviewed for final assessment; 2 out of 7 measurements for U235 are significant, and so all ^{235}U data are included in final assessment.
3	Standard dose assessment	**Assessed Intakes:** ^{234}U = 922 Bq ^{235}U = 20 Bq ^{238}U = 585 Bq **U-tot = 1527 Bq** **Assessed Doses:** ^{234}U = 6.29 mSv ^{235}U = 0.12 mSv ^{238}U = 3.35 mSv **U-tot = 9.76 mSv**	**Note:** There is a question as to whether this assessment be performed on just the first result, or upon all the data? This is a possible exercise artefact in that all the data is immediately available whereas this wouldn't be the case for a real response. However, the final outcome is still the same in this case. **Background subtraction**: ISO16638-1: *requires that natural background should be subtracted from the measurement data, provided that it can be shown that this value is representative of the natural background level for the worker to whom it is applied.*

		Go to Step 4	ISO27048: refers to the measurement parameter *M'* when calculating standard assessment, which <u>does not</u> include background subtraction. Therefore measurement data is used <u>without background subtraction</u>, but the final assessed dose should be tested for the significance of excluding background. (Alternatively: if an allowance for background is subtracted from the results then it will require to be demonstrated to be representative for the individual, which is not possible from Case Description.) **Dose assessments by nuclide:** The measurement for all nuclides are deemed to be significant (Step 2) ISO27048: *For exposures to mixtures of radionuclides where measured values* M' *have been obtained for each radionuclide, Equations (7) (*intake*) and (8) (*CED*) should be used directly, and the values of E(50) for each nuclide summed.* Therefore separate assessments are performed for each nuclide from the specific measurement data sets for the nuclide. **Dose assessment for multiple measurements:** RP188 Step 3 is strictly applicable for assessments from single measurements; however, as multiple data is already provided, the assessment is based on all measurement data, using maximum likelihood equation E.9 in RP188 Step 6. (i.e. for this case Steps 4 and 5 are bypassed in effect) **Default parameters**: - inhalation[1] - single acute intake at midpoint between start date and first sample[2] - lung absorption type S[3] - AMAD of 5 micrometer[3] [1] RP188: *pure inhalation should be assumed as a default unless there is clear evidence for pure ingestion* [2] RP188: *Best estimate of the time (or time interval) of intake* ISO27048: *The calculation of the dose should not be based on the assumption of an intake at the midpoint of a monitoring interval; here, the best estimate of the time of intake, together with all information available, shall be used* However, there is no evidence to identify 'the best estimate of the time of intake' and so the assessment procedure reverts to that for Routine Assessment: i.e. *the time of intake is assumed to be*

			at the mid-point of the monitoring interval (RP188). [3] *a priori* data supplied in Case Description Calculation by manual/spreadsheet method (not using software)
4	Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit	Clearly E(50) > 1/SF[2] mSv **Go to Step 5**	
5	Confirm assumption and findings related to exposure scenario	Additional data already available **Go to Step 6**	
6	Check if the evaluated dose potentially exceeds the annual dose limit	Potential for intake > 20 mSv cannot be excluded. **Go to IDEAS Stage 4**	Using ISO27048 Annex curve for Nat U. (F/M/S) at day 100 (max possible time from unknown intake date to first measurement); comparison for 1st measurement indicates potential to exceed 20 mSv; therefore no further tests needed for subsequent measurements. It might be considered that the isotopic mix is not reliably representative of Nat-U; in which case RP188 Eqn E.8 might be used as the test instead (the result is the same, if applied to ^{234}U).

Table 7-4: adapted from IDEAS Guidelines (Version 2): Stage 4.

Step	Indication	Result	Justification
4.1	Pure inhalation	No evidence of pure inhalation **Go to IDEAS 4.2**	
4.2	Pure ingestion	No evidence of pure ingestion **Go to IDEAS 4.3**	
4.3	Inhalation *and* ingestion	assume inhalation as default **Go to IDEAS Stage 5**	No evidence of either workplace or worker contamination; RP188: *assume pure inhalation as default unless there is information to justify that a part of the intake is ingestion.* No information to justify intake by ingestion; therefore assume inhalation.

Table 7-5: adapted from IDEAS Guidelines (Version 2): Stage 5.

Step	Indication	Result	Justification
STAGE 5A		**Initial assessment with a priori parameter values**	
5.1	Measured data	No evident rogue data **Go to IDEAS 5.2**	
5.2	Contributions from previous intakes	No previous intakes **Go to IDEAS 5.3**	
5.3	*a priori* parameters	**Assigned parameters:** - single intake[1] - lung type S[2] - AMAD of 5 micrometer[3] **Go to IDEAS Step 5.4**	[1] Intake time unknown, so assign RP188 default assumption [2] RP188 recommends lung type M in the absence of specific information for U; the Case Description indicates that the precise chemical form is unknown but states that type S is the *a priori* assignment for monitoring programmes; because this assessment has been triggered by measurements from these monitoring programmes then type S has also been assumed for the assessment, but it is noted that there are arguments to assume type M. [3] RP188 (ICRP) default
5.4	Time of intake	Time of intake is not known **Go to IDEAS Stage 5B**	
5.5/ 5.6	Calculate dose with *a priori* parameters	N/A	
STAGE 5B		**Exposure related parameters**	
5.7	Sufficient dose relevant data	Data considered to be sufficient (and no opportunity to collect further data) **Go to IDEAS Step 5.8**	Data encompasses 6 special urine measurements over a period of 31 days; No faecal measurements are reported.
5.8	Time of intake	Time of intake is not known **Go to IDEAS Step 5.12**	
5.12	Assessment of dose by simultaneous fitting of both the time of intake and the absorption type	**Default Assessment:** E(50)[3] = 9.76 mSv Probability of fit: ^{234}U = 62 % ^{238}U = 63 % ^{235}U = 5 % **Optimal Assessment[5]:**	Assigned parameters for **Default Assessment:** - single intake[1] - lung type S[1] - AMAD of 5 micrometer[1] - time of intake assumed at midpoint[2] [1] a priori and default parameters assigned as from Step 5.3 [2] default assumption (RP188 Step 5.12) Data has <u>not</u> been modified for 'environmental background', as described above in RP188 E.2 Step 3

		Assessed Intake: ^{234}U = 1100 Bq ^{235}U = 24 Bq ^{238}U = 699 Bq **U-tot = 1823 Bq** **Assessed Doses:** ^{234}U = 7.51 mSv ^{235}U = 0.14 mSv ^{238}U = 4.00 mSv **U-tot = 11.7 mSv** Probability of fit: ^{234}U = 71 % ^{238}U = 68 % ^{235}U= 5 %[4] **Go to IDEAS Step 5.12.2**	[3] *E(50)* summed from U234 + U235 + U238; dose for each nuclide assessed separately, as described above in RP188 E.2 Step 3. In this case all the U-235 data was considered as 'real' data, with measurements < DT set to DT/2 (ISO27048 9.2). [4] for U235 the probability of fit and, to a lesser extent, the assessed dose is dependent on treatment of uncertainties as either dominated by Type A or Type B uncertainties; and is also dependent on the choice of treatment of <DT measurement data by use of maximum likelihood (IMBA), assume a value of DT/2 (ISO27048), or treated as 'real' data with the reported uncertainties. However, this is a trivial component of the total dose. **Sensitivity Analysis:** Dose assessments and probability of fit were calculated for both Lung Type S and M, for a single acute intake over the range of possible intake dates. [5]Assigned parameters for **Optimal Assessment:** - same as for Default Assessment except intake date on day 1 (1/2/14) All calculations by use of IMBA; including probability of goodness of fit.
5.12.2	Dose < 6 mSv	Dose > 6mSv **Go to IDEAS Step 5.12.4**	
5.12.4	Sufficient data	Data considered to be sufficient (and no opportunity to collect further data) **Go to IDEAS Step 5.14**	Data encompasses 6 special urine measurements over a period of 31 days; No faecal measurements are reported.
5.14	Assessment of dose by simultaneous fitting of both the time of intake and the mixture of default absorption types (F,M,S)	No further data is available (or possible); An adequate fit has already been reported in Step 5.12. **Go to IDEAS Stage 5C**	
STAGE 5C		**Advanced evaluation**	
5.15	Goodness of fit	Goodness of fit is acceptable; The 'Optimal Estimate' from Step 5.12 is taken as the 'Best Estimate' Record dose estimate and parameters	It is noted that *RP188: Table E.2 Step 3* (above) required that the effect of <u>not</u> subtracting environmental background should be considered in the final assessment. Values for natural background levels expected in urine are taken from IDEAS Table 4.1. Spencer 1990; these values were subtracted from measurements for ^{234}Uand ^{238}U and the intake/dose re-assessed.

		ASSESSMENT TERMINATES	It was found that the total dose is reduced from 11.7 mSv to 8.90 mSv, but with a significantly worse fit to the data: 37 %. This fit is not improved by varying intake time and solubility. It is also noted that this lower estimate is still with the 95% CI (based on goodness of fit) for the final assessment. It is also noted that it is not possible to determine if these background values are representative for the individual. For these reasons the 'Optimal Estimate' from Step 5.12, assessed without any background subtraction, is recorded as the best estimate.

7.3 Overall measurements statistics for the participant solutions

7.3.1 *Estimates of Intake and Committed Effective Dose*

The overall statistics for the solutions submitted are recorded in Table 7-6 and Table 7-7, for intake and committed effective dose respectively.

The Tables also indicate the ICIDOSE Reference Solution (Ref) together with the interval range of +/- a factor of three, which is considered to indicate the acceptable range of divergence from the ICIDOSE Reference Solution, as derived from requirements in ISO20553 (ISO 2006) although it is acknowledged that this reference is strictly applicable for the design of routine monitoring programmes rather than the retrospective estimation of dose.

Table 7-6: overall statistics of solutions submitted for estimates of intake.

Number of submissions	38
Quantity	Intake
Unit	Bq
**Parameters excluding outliers*	
***GM**	963.5
***GSD**	1.66
Number of outliers	4
Parameters including outliers	
***Min**	3.37
Max	2080.00
***Ratio Max/Min**	617.2
Robust mean (RM)	939.3
Robust st. dev. (RSD)	648.2
RSD / RM (%)	69.0
ICIDOSE Reference value (Ref)	**1823**
Ref/3	607.7
Ref*3	5469.0
Number of data less than Ref/3	13
Number of data greater than Ref*3	0

** excludes 'zero' estimate: Participant PID 8*

Table 7-7: overall statistics of solutions submitted for estimates of committed effective dose.

Number of submissions	38
Quantity	E(50)
Unit	mSv
**Parameters excluding outliers*	
***GM**	6.36
***GSD**	1.62
Number of outliers	8
Parameters including outliers	
***Min**	0.003
Max	11.80
***Ratio Max/Min**	4486.7
Robust mean (RM)	5.6
Robust st. dev. (RSD)	4.4
RSD / RM (%)	79.0
ICIDOSE Reference value (Ref)	**11.7**
Ref/3	3.9
Ref*3	35.1
Number of data less than Ref/3	15
Number of data greater than Ref*3	0

** excludes 'zero' estimate: Participant PID 8*

The frequency distribution of the solutions submitted for intake and committed effective dose are displayed graphically in Figure 7-1 and Figure 7-2.

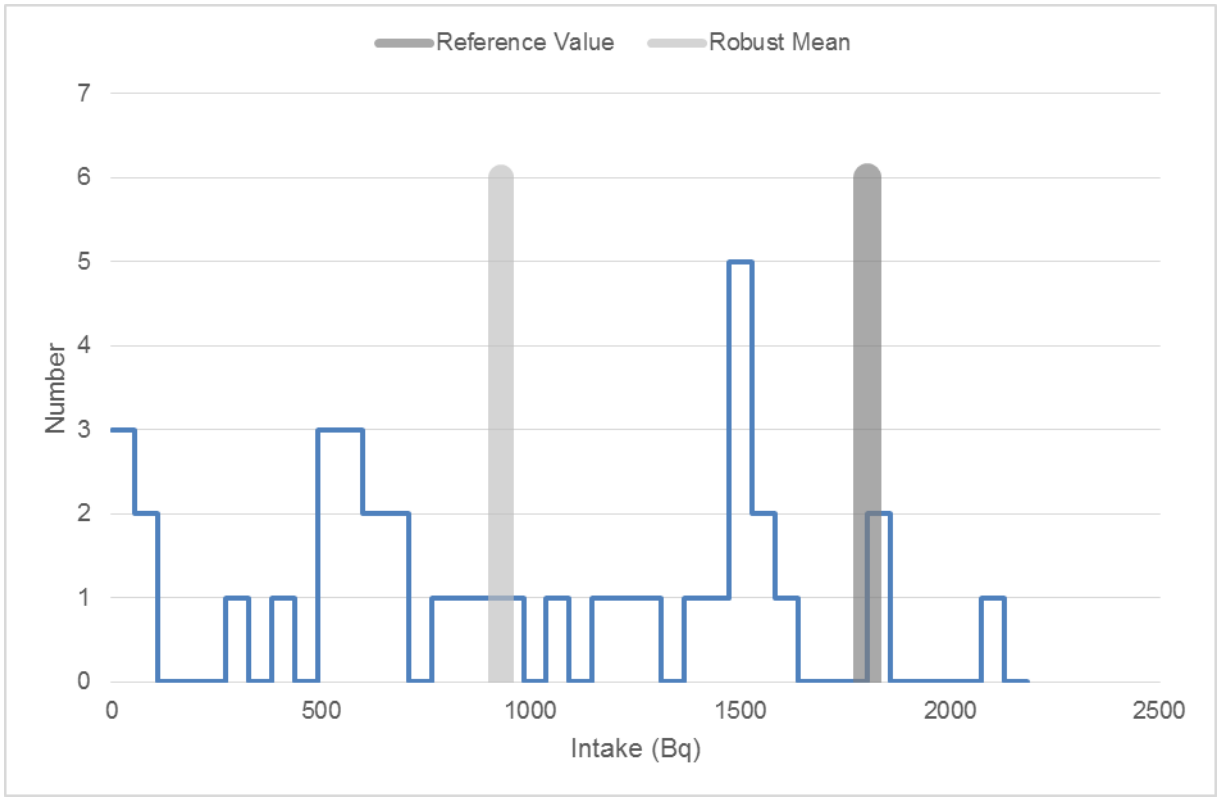


Figure 7-1: Case 3 Frequency distribution of final estimates of total intake (Bq).

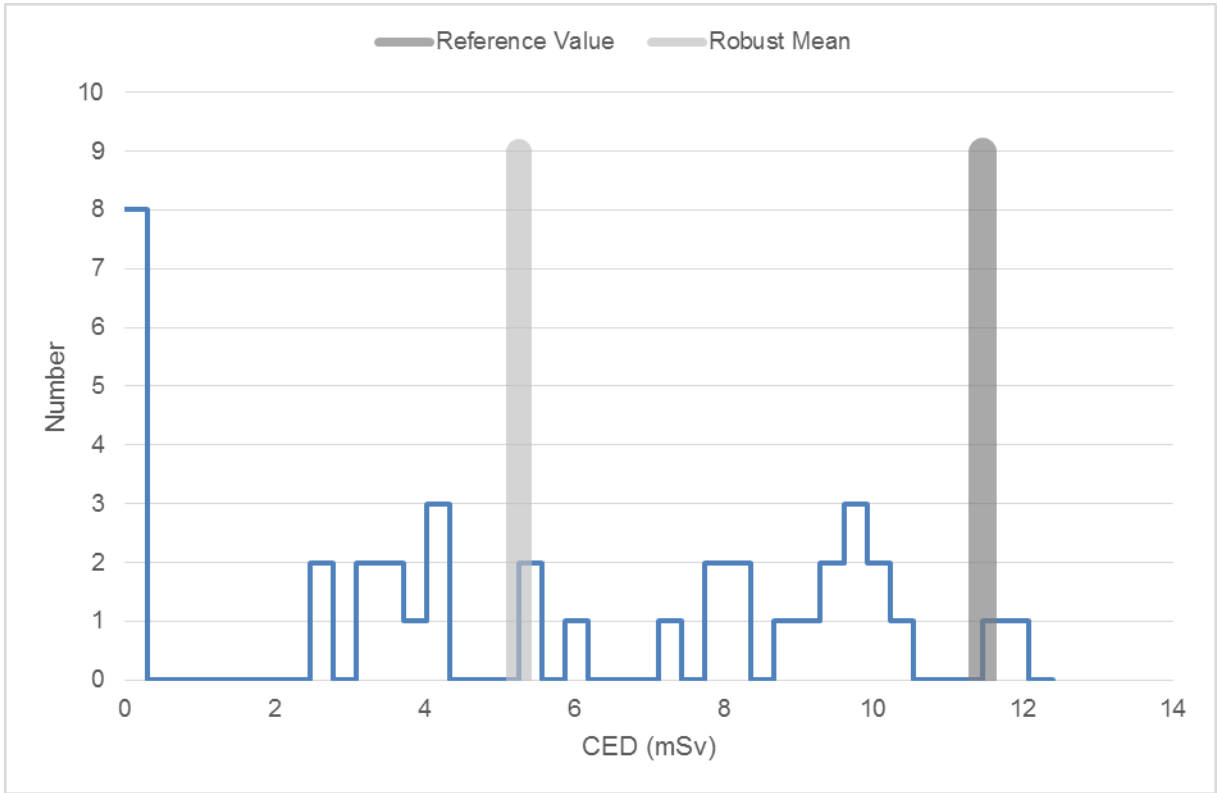


Figure 7-2: Case 3 Frequency distribution of final estimates of committed effective dose (mSv).

It is observed from these figures that there are apparent multiple modes in the distribution of the results. This is more clearly emphasised in Figure 7-3 and Figure 7-4, which present histograms of the single values submitted by each participant, identified by the PID number, for intake and committed effective dose respectively. These histograms have been colour-coded to indicate the exposure pathway that each participant assumed in their assessment. The histograms have been normalised to a Y-axis value (intake or dose) set to the value obtained from the Reference Solution (section 7.2). N0te that participant PID 8 reported a nil estimate for both intake and dose, and so is not represented on the histograms.

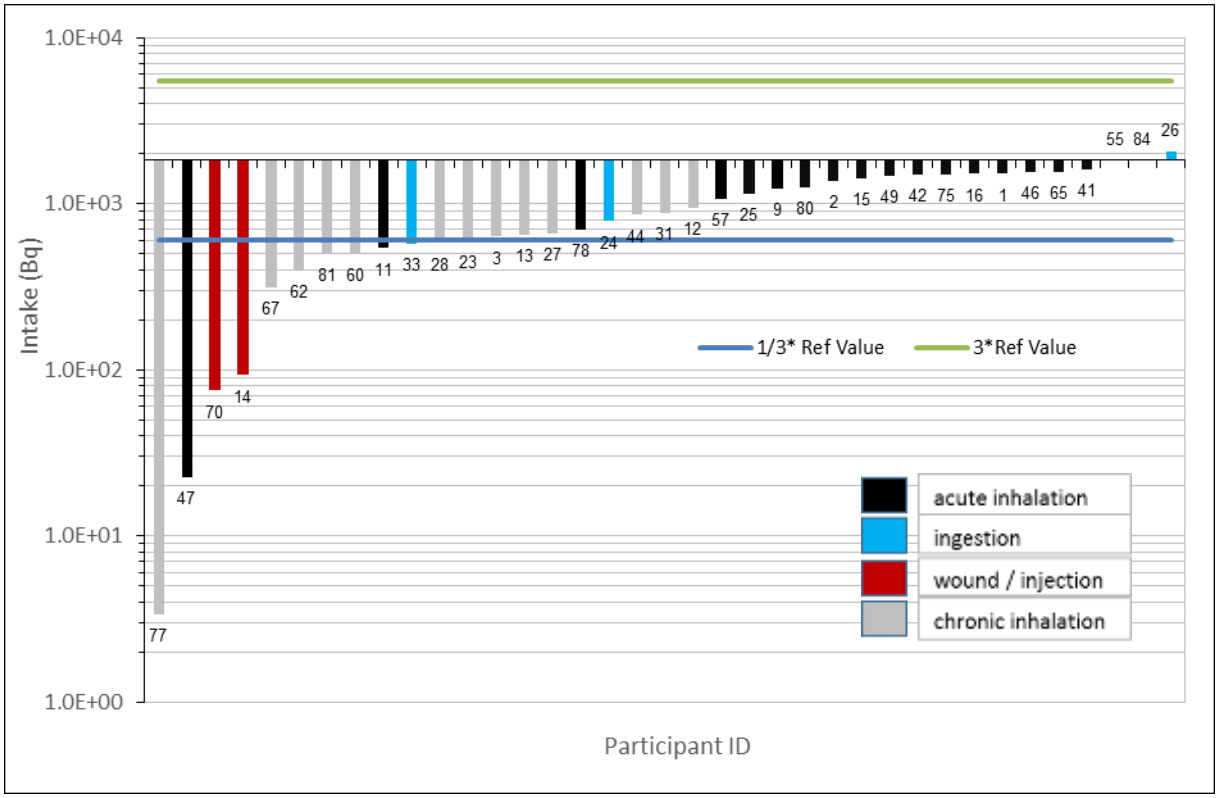


Figure 7-3: Case 3 Histogram of intake values.

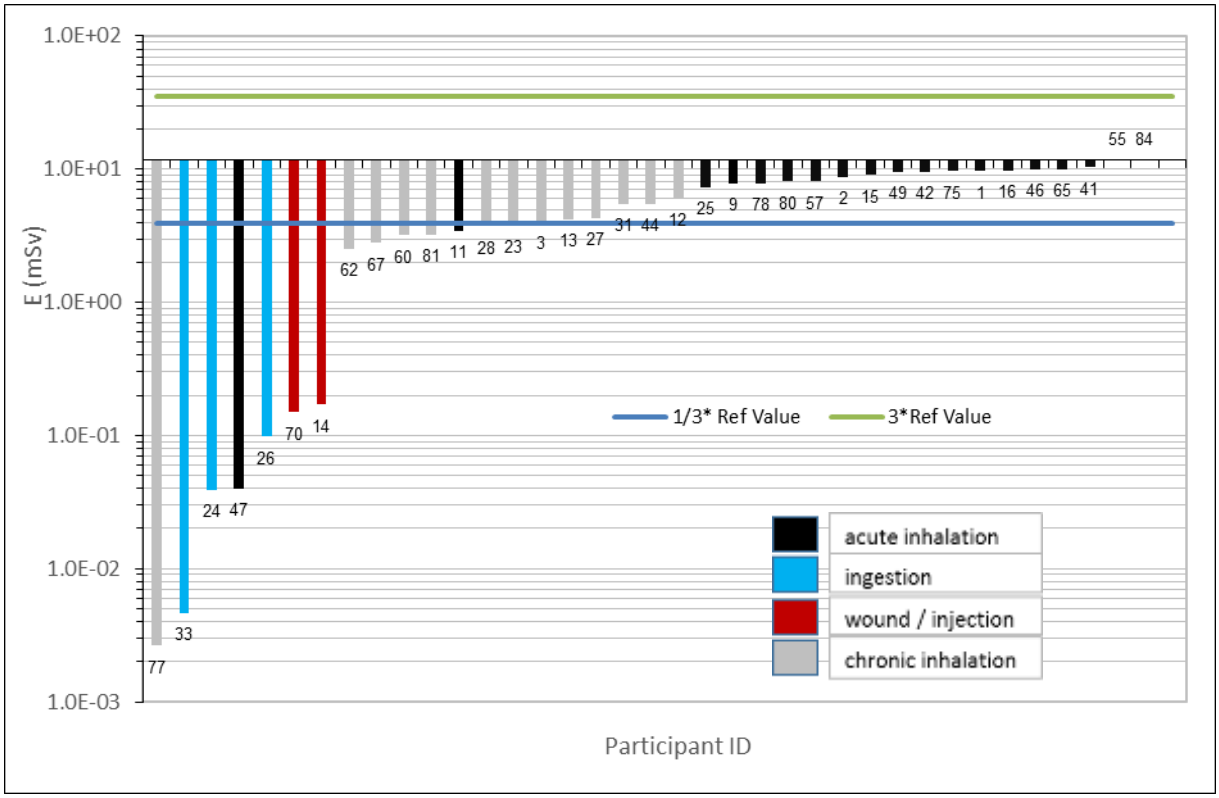


Figure 7-4: Case 3 Histogram of committed effective dose values.

7.3.2 *Comparison between initial and final estimates of intake*

A number of participants have assumed exposure pathways which are different from a single acute inhalation, as determined in the ICIDOSE Reference Solution; and some have assumed different pathways for initial and final estimates. In this analysis it is considered meaningful only to include those submissions which have assumed a single acute inhalation for both initial and final estimates: this is a total of 17 (45% of all submissions for this case). The chart in Figure 7-5 includes a superimposed trend-line, with a forced origin at ordinate (0,0); this indicates that on average final estimates are a factor 1.647 greater than for initial estimates. The correlation coefficient (R^2) for these data sets is 0.5, which indicates a reasonable linear correlation. A similar relationship and statistics were obtained for estimates of committed effective dose.

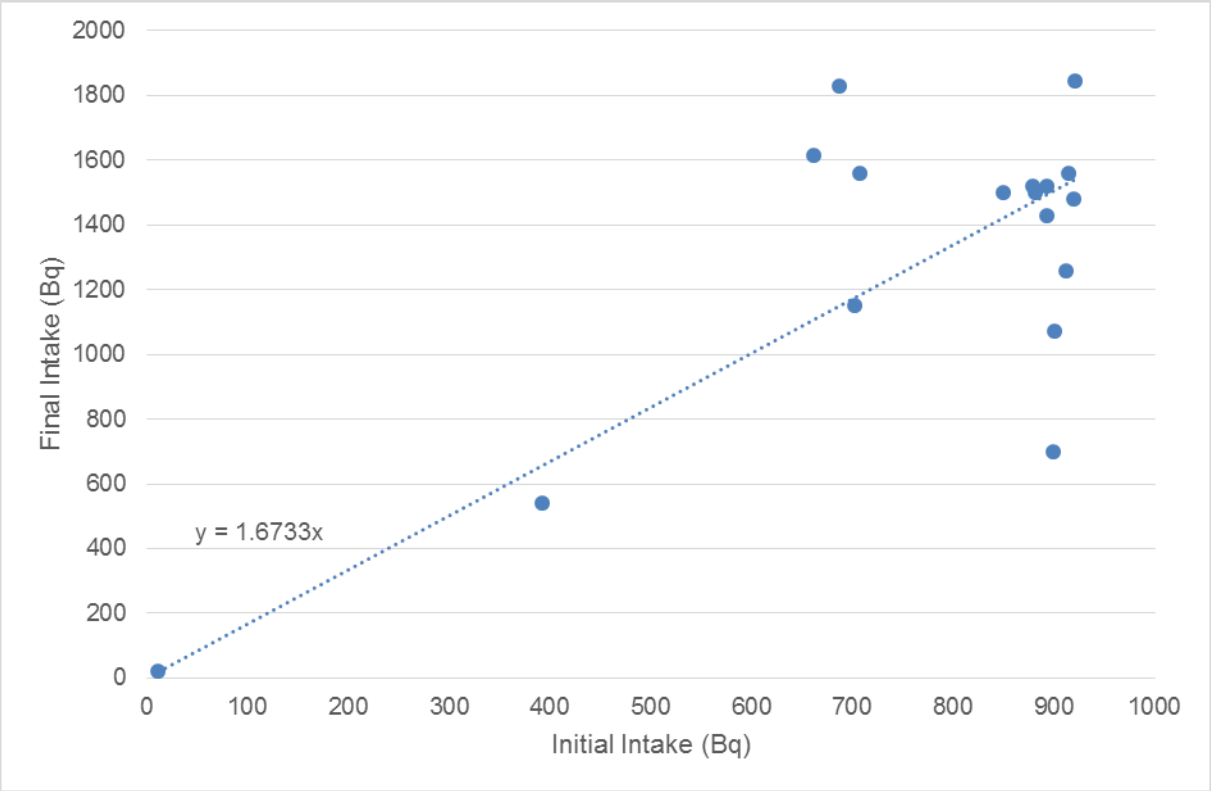


Figure 7-5: Case 3 scatter plot of initial intake estimate v. final intake estimate (only submissions considering acute inhalation in both instances.

7.3.3 *Deriving estimates for a mix of multiple radionuclides*

Table 7-8 provides a summary of the various methods that were used to report total intake and committed effective dose, derived from the measurement data reported for individual radionuclides: ^{234}U, ^{235}U ^{238}U.

Table 7-8: Summary of methods used for assessing mix of radionuclides.

Method	*Number of submissions*	*(%)*
individual direct estimates for each radionuclide	21	*55*
estimate from a single radionuclide used as a 'tracer' for mix	2	*5*
Sum each radionuclide and estimate for total uranium	6	*16*
Other: *assumption all data due to environmental exposure;* *^{234}U and ^{238}U estimated directly, ^{235}U excluded;* *^{234}U and ^{238}U summed, ^{235}U estimated by ratio;* *all nuclides summed then assumed ^{234}U dose coefficient;* *^{234}U and ^{238}U estimated directly, ^{235}U by ratio to ^{238}U;* *^{234}U and ^{238}U summed, ^{235}U excluded;*	9	*24*

7.4 Observations and discussion on selected aspects

This section discusses the principal observations, from the solutions submitted by participants, which are considered to have a significant impact on the final estimates. It is noted that divergent methodologies have been applied in four key areas: the assumption of exposure pathway; the derivation of estimates of intake and dose for total uranium from measurement data for three discrete radionuclides; whether to allow for contributions from non-occupational exposures; the use of measurement data indicated to be less than the Decision Threshold. These observations are summarised below and are compared to the determined ICIDOSE Reference methodology in section 7.5.

7.4.1 *Assumption of exposure pathway*

It should be noted that the Case Description (section 7.1) includes no information on the possible exposure pathway; therefore the participant is required to determine what the most appropriate assumption should be. A range of assumptions have been applied; those used for deriving the final estimates of total intake and dose are summarised in Table 7-9.

Table 7-9: Summary of assumed exposure pathways (final estimate).

Exposure Pathway	*Number of submissions*	*(%)*
Acute inhalation: Intake at **mid-point** between start of work and first sample	8	*21*
Acute inhalation: Intake at **day 1** of work period	5	*13*
Acute inhalation: Other intake times	7	*18*
Chronic inhalation: From day 1 of work period to last sample	10	*26*
Chronic inhalation: Other intake periods	2	*5*
Acute Ingestion (occupational)	2	*5*
Chronic ingestion (occupational)	1	*3*
Non-occupational ingestion	1	*3*
Acute Injection/Wound	2	*5*

7.4.2 *Treatment of radionuclides*

Participants were requested to define how they had combined the data for the three radionuclides into the overall estimate of total uranium intake and dose; three options were proffered on the submission sheet, together with a text box for the participant to describe 'other' methods (section 2.4.2). The results are summarised in Table 7-8 (section 7.3.3). It is noted that nine different methods were reported.

7.4.3 *Allowance for contributions from natural sources on measurement data*

It is noted that the case description (section 7.1) contained no information on the expected radionuclide mix of the suspected source of the exposure; and further indicated that depleted, enriched and natural forms of uranium were all possible. The submission form provided a text box for participants to describe any adjustments that had been made to the data, but did not explicitly refer to allowance for natural contributions. However, a number of participants used this text box to record that they had considered the effects of natural contributions. A total of seven (18%) participants indicated that they had adjusted the measurement data by subtracting an allowance for natural contributions.

7.4.4 *Measurement data indicated as less than Decision Threshold*

The case description provided an indication of the analytical Decision Threshold for each measurement result (Table 7-1), but there was no specific instruction to participants to record if and how they had made use of this information. However, a number of participants indicated their use of this information in the text box for recording any adjustments made to the data. It is noted that all of the measurements for ^{234}U and ^{238}U provided results greater than the respective analytical Decision Thresholds; but that five of the seven results for ^{235}U were below the relevant threshold. A total of six (16%) participants had excluded all ^{235}U measurement data from the final estimates, with one participant citing the prevalence of results less than decision thresholds as the reason for doing so; one participant included an estimate for ^{235}U in the final estimate, but only based on the two measurement results greater than the Decision Threshold.

7.4.5 *Comparison between accredited and non-accredited centres*

The fact that institutions had some kind of certification does not seem to play any role in the accuracy of the submitted results, as is evident in the distribution chart for assessed Committed Effective Dose, Figure 7-6.

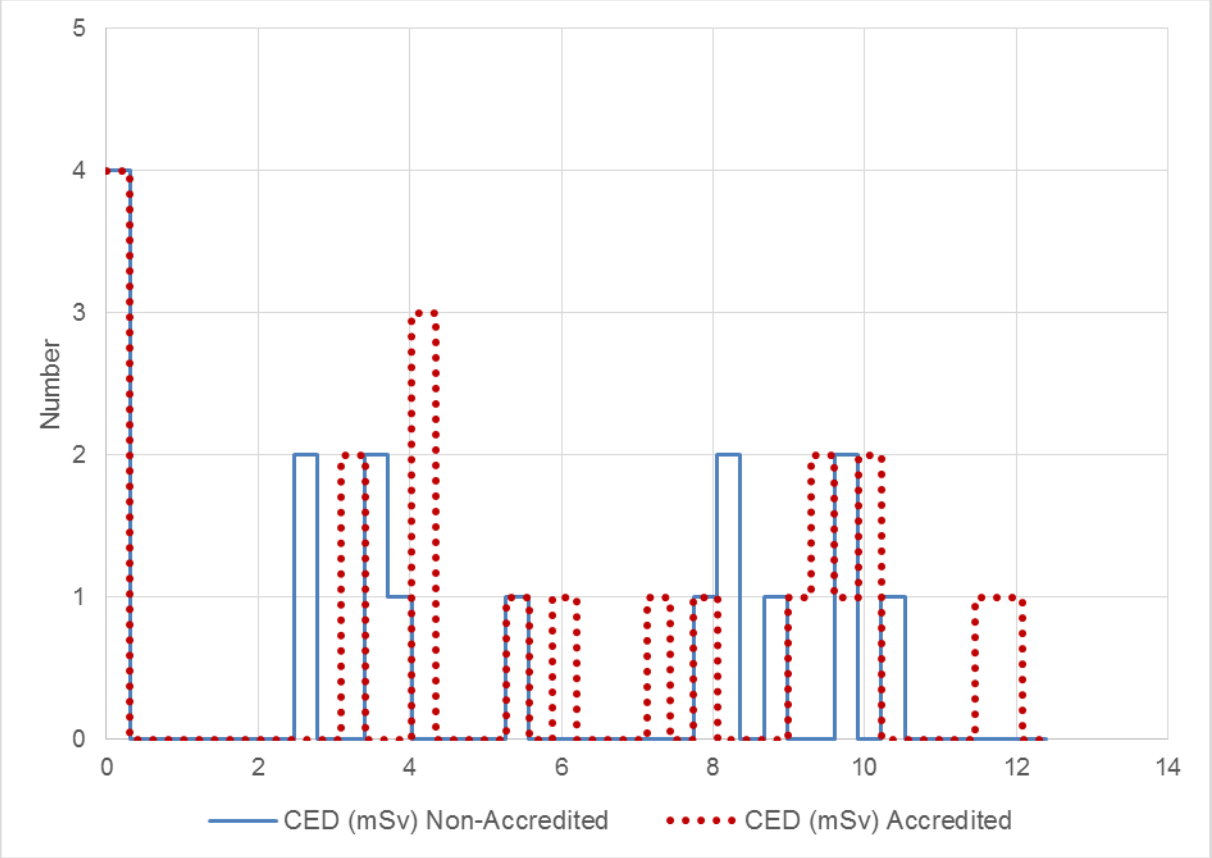


Figure 7-6: Comparison of the distribution of the results for committed effective dose (mSv) between participants with accreditation (dotted red line) and without accreditation (solid azure line).

7.4.6 *Use of Software*

The majority of participants used the IMBA software program, with various versions, as indicated in Table 7-10. Figure 7-7 compares the frequency distributions of committed effective dose for

participants who reported the use of specialist software, and those which did not. However, the various different assumptions made regarding exposure pathway, treatment of the radionuclide mix and other subjective judgements means that it is not feasible nor meaningful to attempt any conclusions on the impact of the use of software.

Table 7-10: Used software and number of submissions relative to the used software.

Used Software	*Number of submissions*
IMBA	24
AIDE	1
MONDAL	2
MMK-02	1
DCAL	1
CALIN	1
None (includes the reported use of MS Excel)	8

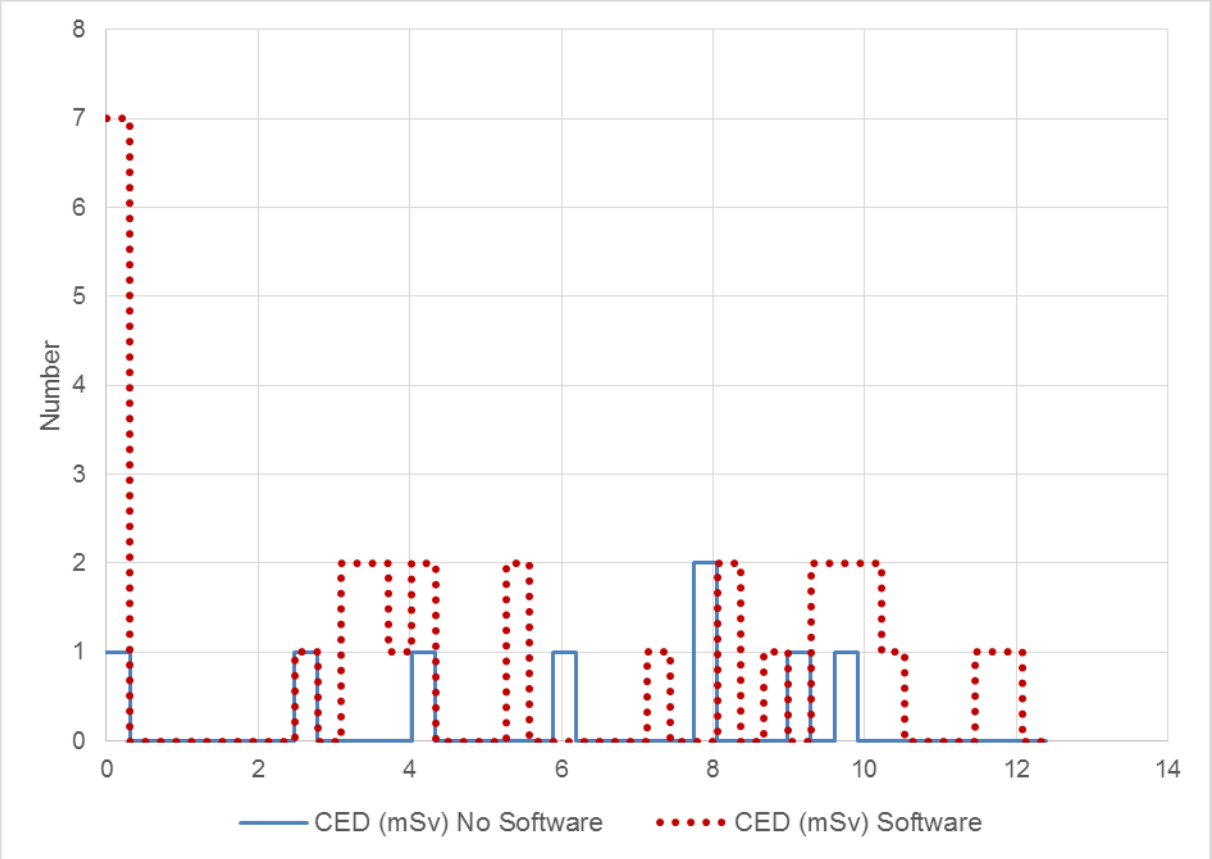


Figure 7-7: Comparison of the distribution of the results for committed effective dose (mSv) between participants using specialist software (dotted red line) and those not using specialist software (solid azure line).

7.4.7 *Step at which the analysis was terminated*

Table 7-11 provides a summary of the procedural step, as defined in RP188 (and IDEAS, if appropriate), at which the submitted solutions terminated.

Table 7-11: Terminating step in RP188.

Terminating Step		*Number of submissions*
RP188: Section E2 (Routine) Step 4		2
RP188: Section E2 (Routine) Step 5		1
RP188: Section E2 (Routine) Step 6		3
RP188: Section E2 (Routine) Step 7		1
RP188: Section E2 (Routine) Step 8:	IDEAS: Stage 5A Step 5.6	1
RP188: Section E2 (Routine) Step 8:	IDEAS: Stage 5B Step 5.11.3	1
RP188: Section E2 (Routine) Step 8:	IDEAS: Stage 5C Step 5.15.1	1
RP188: Section E3 (Special) Step 1:		2
RP188: Section E3 (Special) Step 4		1
RP188: Section E3 (Special) Step 5:		1
RP188: Section E3 (Special) Step 6:		5
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 4 Step 4.4	1
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5B Step 5.11.1	1
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5B Step 5.11.3	1
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5B Step 5.12.3	1
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5B Step 5.13	1
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5C Step 5.15	3
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5C Step 5.15.1	7
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5C Step 5.15.5	2
RP188: Section E3 (Special) Step 6:	IDEAS: Stage 5C Step 5.21	1
Not specified		1

7.5 Errors performed by participants during the assessment

These errors are considered to be of two types: Reporting errors and Method errors.

Reporting errors refer to mistakes that have occurred by erroneously recording incorrect data on the submission form: e.g. "Sv" instead of "mSv"; data processing errors: e.g. as a result of a comma "," being used instead of a dot "." as the decimal separator, etc. All submissions were reviewed to try and identify such errors, and the participant contacted to confirm the correct reported data. In some circumstances it was also evident that participants had not correctly understood the instructions issued with the case descriptions. Where such reporting errors were confirmed by the participant then the corrected data has been used in this report. No detailed analysis or discussion is considered for such errors, as this was not an objective of the intercomparison.

Method errors refer to instances where the methodology applied by participants is considered to be inconsistent with that which is recommended by RP188, as summarised in the ICIDOSE Reference Solution (section 7.2). (This does not necessarily imply that the participant's solution is incorrect or worse than the ICIDOSE Reference Solution.) This is particularly addressed to the four observations highlighted in section 7.4 and discussed below.

7.5.1 *Assumption of exposure pathway*

A number of different assumptions were made by the participants. Here we justify in details the choice made for the Reference Solution and indicate why other choices are not consistent with RP188, and their effects on the dose estimates.

ICIDOSE Reference Solution: Acute Inhalation on Day 1

In the ICIDOSE Reference Solution the relevant steps are, firstly, Step 3 of Chapter E.3 *Dose Assessment and Interpretation: Special Monitoring:* 'Standard dose assessment'. This states that for the intake route *"…pure inhalation should be assumed as a default unless there is clear evidence for pure ingestion (i.e. there is evidence that is well-established and documented)"*. It further states that the *"best estimate of the time (or time interval) of intake"* should be assumed, with the presumption that the *"time of intake is usually known".* However, in this case, the solution method progressed to Special Assessment due to the report of a urine sample (from a confirmatory monitoring programme) above a predefined Investigation Level; and there was no evidence in the Case Description to identify the best estimate of the time of intake. Therefore it is considered that the solution procedure reverts to the default assumption defined for Step 3 of Routine Assessment: i.e. the time of intake is assumed to be at the mid-point of the monitoring interval. Therefore, at this point of the solution method, the assigned assumptions for standard dose assessment are for an acute inhalation occurring at the mid-point between the first day of work and the first urine sample: i.e. 22/3/2014.

The solution then progresses to the next relevant step, being Stage 4 of the IDEAS Guidelines. There is no evidence to specifically identify either inhalation or ingestion as the exposure pathway; in this instance IDEAS Step 4.3 recommends to "*assume pure inhalation as default unless there is information to justify that a part of the intake is ingestion*" and to proceed to Stage 5. It is noted that RP188 recommends proceeding to IDEAS Stage 7 for mixed inhalation / ingestion pathways if "*the possibility of ingestion with simultaneous inhalation cannot be ruled out*", which is the situation in this case. This is in apparent conflict with IDEAS Step 4.3; however, IDEAS Step 7.3 indicates that the default assumption for mode of intake is 100% inhalation; the inhaled fraction is only challenged if an acceptable goodness of fit cannot be obtained. The ICIDOSE Reference

Solution proceeds from IDEAS Stage 4 to IDEAS Step 4.3 to IDEAS Stage 5 (for pure inhalation). An acceptable goodness of fit is readily achieved, therefore there is no requirement to consider a mixed inhalation/ingestion pathway (this is the same conclusion as would have been obtained had the assessment followed the IDEAS Stage 7 route).

The reference solution then progresses to IDEAS Stage 5B and eventually to Step 5.12, which indicates that an intake occurring at the mid-point of the monitoring period should be assumed (i.e. 22/3/2014). This assumption provides an acceptable goodness of fit. However, this step indicates that "*If an acceptable fit is found, it is likely that acceptable fits will be found for a range of times of intake, and therefore the combination of absorption type and time of intake giving the best fit is chosen.*" Therefore, fits are made using day of intake as free parameter, and the optimum fit is found for an assumption of an inhalation intake (of Type S material) occurring on the first day of the monitoring period (i.e. 1/2/2014). This is then assumed for the final assessment in the ICIDOSE Reference Solution.

Intake via wound/injection

It is noted that Step 1 of Chapter E.3 *Dose Assessment and Interpretation: Special Monitoring* states that *"If an intake via wound or skin, or influenced by decorporation therapy, cannot be ruled out"* then the assessment progresses on the assumption of an intake by wound. (This clause is as stated in ISO 27048 (ISO 2011).) A strictly literal application of this clause would mean that, because it is not logically feasible to *rule out* a wound, then the assessment should proceed as if for a wound. However, it is believed that this is not the intention of this clause. The interpretation applied by the ICIDOSE Reference Solution is that because there is no reason to suspect a wound, then an intake via wound is not considered. It is acknowledged that this is a different literal application of RP188; and that those participants who assumed an intake via wound are not strictly incompatible with RP188. However, the mean assessed committed effective dose reported by participants who used this method is approximately **70 times lower** than the Reference Solution; and is therefore considered to be an unreliable assessment unless supported with further justification than is reported in the Case Description.

Intake via ingestion

It is evident from the above discussion on the ICIDOSE Reference Solution that an assumption of intake via ingestion is not consistent with RP188, unless supported with further justification than is reported in the Case Description. The mean assessed committed effective dose reported by participants who used this method is approximately **300 times lower** than the Reference Solution.

Intake via chronic inhalation

It is evident from the above discussion on the ICIDOSE Reference Solution that an assumption of intake via chronic inhalation is not consistent with RP188, unless supported with further justification than is reported in the Case Description. The mean assessed committed effective dose reported by participants who used this method is approximately **3 times lower** than the Reference Solution.

Intake via acute inhalation at mid-point

The decision to apply this method depends on not applying the optimised fitting consideration, as described in the text of IDEAS Step 5.12. It is noted that an assessment based on the assumption of a mid-point intake provides a good fit (probability = 62% for the ^{234}U assessment), as compared to that obtained by the Reference Solution (probability = 71% for the ^{234}U assessment).The impact of

neglecting to look for the best fit is limited, as the dose is underestimated by a **factor of 1.3**. So in this case this method turns out not to be an unreasonable application of RP188.

7.5.2 *Treatment of radionuclides*

RP188 Chapter E.3 *Dose Assessment and Interpretation: Special Monitoring:* Step 3 'Standard dose assessment' indicates that assessments for exposures to mixtures of radionuclides should follow the methodology described in ISO 27048 (ISO 2011). Step 7.1.3 of ISO 27048 indicates that dose assessments should be performed directly for each radionuclide, with the resultant values of *E(50)* being summed to obtain an estimate of the total dose. However, it also indicates that assessments of *E(50)* from one radionuclide can be used as a tracer for other nuclides by application of known ratios for radionuclide abundance and dose coefficients. Although not specifically referenced in the assessment procedure, RP188 contains a general reference to ISO 16638-1 *Monitoring and internal dosimetry for specific materials* (ISO 2015b). The application of this standard implies that 'reference levels' are compared to the 'total alpha' content of measurement data; and that compound-specific *e(50)* values should then be used to assess the effective dose. Therefore the various methods employed for this case can be equally considered as valid applications of RP188. It is noted that the choice of method can impact the dose assessment for ^{235}U by a factor of 2, but that this has a non-significant impact to the total dose.

7.5.3 *Allowance for contributions from natural sources on measurement data*

RP188 Chapter D highly recommends that pre-work, blank bioassay samples are obtained before starting work with potential for occupational exposures to radionuclides which also have a potential for environmental exposure. However, there was no information on pre-work samples included in the case description. The only information provided that might have been of relevance was to identify the country in which the exposure occurred, which could then be referenced to studies on environmental excretion rates published in the IDEAS Guidelines, for example. RP188 requires that for any adjustment made for the contribution from natural sources "*it must be demonstrated that the reference value is representative of the natural background level for the worker to whom it is applied*". The ICIDOSE Reference Solution considered that merely identifying the country was not sufficient justification by itself, and that therefore for this case it is not justified to make any allowance for contributions from natural sources.

RP188 requires that "*if natural background levels are not taken into account, it should be demonstrated that their contribution to assessed dose is not significant.*" The Reference Solution considered the environmental excretion rates reported for UK by Spencer (1990), IDEAS Table 4.1. If these values are subtracted from the measurement data then the final assessed committed effective dose is reduced by 24 %. This reduction lies within the 95% confidence interval of the estimate for the reference solution (as determined by the Bayesian analysis tool in IMBA™), and does not transport the dose estimate across any relevant decision threshold, and so is not considered to be significant. The corollary is that, for those participants who made corrections for natural background, then although this approach is not considered to be justified by RP188 (in this case), the impact on the assessed dose is not significant.

7.5.4 *Measurement data indicated as less than Decision Threshold*

This discussion is specifically relevant to the ^{235}U assessment, which comprises five out seven measurement data which are less than the Decision Threshold. The first relevant test is to

determine if the data is significant, as described in RP188 Chapter E.3 *Dose Assessment and Interpretation: Special Monitoring:* Step 2 'Check if the measured value is significant'. This step does not specifically address how to handle multiple data; however, the Reference Solution applies the same principle as contained in Step 6 for comparing dose assessments from multiple data to dose limits. This indicates that the test is satisfied for the whole data set if the test is satisfied for at least 5% of individual sample data. Therefore the ^{235}U data as a whole data set is considered to be significant, and is used to derive a dose assessment.

The next step is to consider how to include data which is less than Decision Threshold in the calculation of intake and dose. This is addressed in ISO 27048 paragraph 9.2 (ISO 2011) which indicates that either the maximum likelihood method can be used (with aid of dedicated software), or by simply assigning a numerical value equal to half the Decision Threshold to each result less than the Decision Threshold. This was the approach adopted by the Reference Solution, which was within 20% of the value estimated by the maximum likelihood method.

It is considered that participant solutions which excluded some or all of the ^{235}U data are not strictly compatible to application of RP188; however, the impact of this on the final assessed total dose is trivial (about 1%).

8. Case 4

8.1 Case description

The Event

Description of the working area

Well-equipped room in a radioactive waste treatment and disposal facility

Characteristics of work

On the 2nd December 2010 the worker involved in the action opened a previously closed drum containing radioactive wastes of ^{241}Am, in order to sort the waste according to their physical state and compressibility. The aim was to reduce the volume of the waste. The drum contained wastes of ^{241}Am isotope with activity of giga-becquerel order of magnitude. The worker had to wear respiratory protective mask for this operation, but it was not checked and proved. After the work had finished some contamination on his hands and clothes was detected.

Reasons for monitoring; initiating event

Two days later the worker was subject to routine confirmatory monitoring by whole body counting; this monitoring was conducted without knowledge of the given event. ^{241}Am contamination was detected in the whole body spectra. This was the point when the monitoring service became aware of the event. It turned out that certain body surfaces and clothes were also contaminated. He returned for repeated measurements on the ninth day after the event, after careful decontamination. Using profile scanning measurement it was found that the great majority of contamination was located in the lung area.

Actions taken

Based on the results of the measurement, initial dose estimation was performed with the MONDAL code, assuming inhalation as intake pathway and ICRP default parameter values; and then reported to the authorities. Since the magnitude of the estimated committed effective dose essentially exceeded the annual dose limit further investigations were decided. Follow-up investigation was continued mainly in a dedicated institute by direct chest counting and urine bioassay for an extended period. DTPA treatment started 19 days after the event. Efforts were also been made to investigate the chemical and physical characteristics of the contaminant that comprised the intake.

Additional information

Air monitoring

None

Chemical form

The original compound was very probably Am sulfate in soluble form soaked up with filter paper and dried. This was the form of the contaminant when the drum has been opened and the intake occurred.

Physical characteristics, particle size

Because the contaminant became dusty the investigation determined it likely that the activity had been attached on particles and fibers that might be in a broad range of micrometers.

Nose swab, bronchial slime or similar

None

Non removable skin contamination

Considerable skin surface contamination was detected at the very beginning. Despite the strong efforts in order to complete the decontamination, it is possible that, in the first one to two weeks, the skin contamination influenced the monitored lung activity data.

Wound site activity

Not relevant

Any intervention used (blocking, chelating, etc.)

DTPA treatment for an extended period.

1g Ca/Zn-DTPA in 100 ml infusion was administered intravenously in the first period daily, and after that twice a week.

Individual monitoring data

Organ activity measurement

Data on lung activities are available

Whole body activity measurement

None

Excretion monitoring data

Urine activity measurements

Urine data are available.

Feces activity measurement

None

Personal Data

Sex

Male

Age

27 y

Weight

78 kg

Other comments relevant for dose estimation

Inhalation is the predominant pathway.

Although 24-hour urine sampling was requested from the worker, it turned out that it could not be considered that this advice was strictly adhered to. Therefore, the activity concentrations were primarily recorded and finally normalized to assuming 1.6 litre urine excretion per 24 hours; both data sets are given in the provided table.

During the DTPA treatment there were no appropriate monitoring data available to satisfy the criteria stated in the RP188 in order to be able to determine the DTPA enhancement factor.

The relative uncertainties given in the urine activity table refer to the counting statistics only and were taken as typical values from the IDEAS Guidelines (Fig. 4.1).

The relative uncertainties given in the lung activity table refer to the counting statistics only.

Contributions from other part of the body were assumed in the monitored lung activity data.

The Detection Limit in urine activity concentration measurement was found to be about 1 mBq/l, whereas for lung counting about 20 Bq.

The time-integrated total activity eliminated by the urine due to the DTPA treatment is estimated to be about 2 kBq.

Table 8-1: Case 4 urine measurement data.

Date	Measured ^{241}Am	Rel. Uncertainty (± 1 SD)	^{241}Am	DTPA Treatment
	[Bq/l]	[%]	[Bq/day]	
11/12/2010	0.87	±10	**1.39**	
12/12/2010	1.59	±10	**2.54**	
13/12/2010	0.53	±10	**0.85**	
16/12/2010	0.77	±10	**1.23**	
17/12/2010	1.03	±10	**1.65**	
20/12/2010	0.25	±10	**0.40**	
21/12/2010	n.a.			DTPA
22/12/2010	38.5	±10	**61.6**	DTPA
23/12/2010	n.a.			DTPA
24/12/2010	n.a.			DTPA
25/12/2010	54.6	±10	**87.4**	DTPA
30/12/2010	n.a.			DTPA
02/01/2011	20.3	±10	**32.5**	DTPA
07/01/2011	n.a.			DTPA
09/01/2011	18.3	±10	**29.3**	DTPA
14/01/2011	n.a.			DTPA
16/01/2011	16.9	±10	**27.0**	DTPA
21/01/2011	n.a.			DTPA
23/01/2011	14.8	±10	**23.7**	DTPA

28/01/2011	n.a.			DTPA
30/01/2011	n.a.			DTPA
04/02/2011	13.3	±10	**21.3**	DTPA
06/02/2011	n.a.			DTPA
13/02/2011	5.97	±10	**9.55**	
16/02/2011	8.02	±10	**12.8**	
19/02/2011	4.96	±10	**7.94**	
25/02/2011	2.01	±10	**3.21**	
10/03/2011	0.74	±10	**1.18**	
24/03/2011	1.53	±10	**2.45**	
25/03/2011	n.a.			DTPA
27/03/2011	n.a.			DTPA
01/04/2011	3.1	±10	**4.96**	DTPA
03/04/2011	n.a.			DTPA
08/04/2011	n.a.			DTPA
10/04/2011	n.a.			DTPA
28/04/2011	1.2	±10	**1.92**	
05/05/2011	0.65	±10	**1.04**	
06/05/2011	n.a.			DTPA
08/05/2011	n.a.			DTPA
11/05/2011	0.72	±10	**1.15**	DTPA
15/05/2011	n.a.			DTPA
20/05/2011	n.a.			DTPA
22/05/2011	n.a.			DTPA
26/05/2011	0.10	±10	**0.16**	
17/06/2011	n.a.			DTPA
19/06/2011	n.a.			DTPA
23/06/2011	0.84	±10	**1.34**	DTPA
25/06/2011	n.a.			DTPA
30/06/2011	n.a.			DTPA
03/07/2011	n.a.			DTPA
24/07/2011	0.30	±10	**0.48**	

26/08/2011	0.053	±10	**0.085**	
02/09/2011	n.a.			DTPA
06/09/2011	0.76	±10	**1.22**	DTPA
09/09/2011	n.a.			DTPA
11/09/2011	n.a.			DTPA
16/09/2011	n.a.			DTPA
18/09/2011	n.a.			DTPA
30/09/2011	0.32	±10	**0.51**	
13/11/2011	0.042	±10	**0.067**	
12/12/2011	0.053	±10	**0.085**	
06/01/2012	n.a.			DTPA
08/01/2012	n.a.			DTPA
12/01/2012	n.a.			DTPA
16/01/2012	0.44	±10	**0.70**	DTPA
19/01/2012	n.a.			DTPA
22/01/2012	n.a.			DTPA
26/03/2012	0.026	±10	**0.042**	
05/05/2012	n.a.			DTPA
13/05/2012	n.a.			DTPA
21/05/2012	n.a.			DTPA
26/05/2012	n.a.			DTPA
02/06/2012	0.114	±10	**0.182**	DTPA
10/06/2012	n.a.			DTPA
25/06/2012	0.101	±10	**0.162**	
03/09/2012	0.043	±10	**0.069**	

Table 8-2: Case 4 lung measurement data

Date	**Measured ^{241}Am**	**Rel. Uncertainty (± 1 SD)**	DTPA Treatment
	[Bq]	[%]	
13/12/2010	**899**	±10	
17/12/2010	**1070**	±10	
21/12/2010	n.a.		DTPA

22/12/2010	n.a.		DTPA
23/12/2010	n.a.		DTPA
24/12/2010	n.a.		DTPA
25/12/2010	n.a.		DTPA
27/12/2010	**541**	±15	
30/12/2010	n.a.		DTPA
02/01/2011	n.a.		DTPA
07/01/2011	**389**	±20	DTPA
09/01/2011	n.a.		DTPA
14/01/2011	n.a.		DTPA
16/01/2011	n.a.		DTPA
21/01/2011	n.a.		DTPA
22/01/2011	**502**	±15	
23/01/2011	n.a.		DTPA
28/01/2011	n.a.		DTPA
30/01/2011	n.a.		DTPA
04/02/2011	n.a.		DTPA
05/02/2011	**261**	±25	
06/02/2011	n.a.		DTPA
17/02/2011	**220**	±25	
26/02/2011	**307**	±25	
11/03/2011	**279**	±25	
25/03/2011	n.a.		DTPA
27/03/2011	**156**	±30	DTPA
01/04/2011	n.a.		DTPA
03/04/2011	n.a.		DTPA
05/04/2011	**173**	±30	
08/04/2011	n.a.		DTPA
10/04/2011	n.a.		DTPA
15/04/2011	**95**	±35	
29/04/2011	**109**	±35	
06/05/2011	n.a.		DTPA

08/05/2011	n.a.		DTPA
11/05/2011	n.a.		DTPA
12/05/2011	**113**	±35	
15/05/2011	n.a.		DTPA
20/05/2011	n.a.		DTPA
22/05/2011	n.a.		DTPA
27/05/2011	**126**	±35	
17/06/2011	n.a.		DTPA
19/06/2011	n.a.		DTPA
23/06/2011	**161**	±30	DTPA
25/06/2011	n.a.		DTPA
30/06/2011	n.a.		DTPA
03/07/2011	n.a.		DTPA
24/07/2011	**128**	±35	
27/08/2011	**83**	±35	
02/09/2011	n.a.		DTPA
06/09/2011	n.a.		DTPA
09/09/2011	n.a.		DTPA
11/09/2011	n.a.		DTPA
16/09/2011	n.a.		DTPA
18/09/2011	n.a.		DTPA
30/09/2011	**106**	±35	
13/11/2011	**149**	±30	
12/12/2011	**145**	±30	
06/01/2012	n.a.		DTPA
08/01/2012	n.a.		DTPA
12/01/2012	n.a.		DTPA
16/01/2012	n.a.		DTPA
19/01/2012	n.a.		DTPA
22/01/2012	n.a.		DTPA

8.2 Methodology to determine the Recommended Assessment

8.2.1 *Procedural steps of the assessment*

Various possible Reference Solutions - called Recommended Assessment - are presented below in table form, from Table 8-3 to Table 8-6; and are a facsimile of the format used to summarise the procedural steps within RP188 Chapters and IDEAS Guidelines. The solutions intend to follow the RP188 and IDEAS instructions as strictly as possible.

Table 8-3: adapted from RP188: Table E.1 Summary of ISO 27048:2011 procedure for Routine Monitoring

Step	Indication	Result	Notes
1	Check if the method used and the monitoring interval are appropriate for routine monitoring	The circumstances given in the Case Description implies Special Monitoring is required	**Go to Special Monitoring,** **Table E.2 – Step 1**

Table 8-4: adapted from RP188: Table E.2 Summary of ISO 27048:2011 procedure for Special Monitoring

Step	Indication	Result	Notes
1	Check if an intake via wound, intact skin or influenced by decorporation therapy can be ruled out	No evidence of intake via wound or intact skin and no decorporation therapy has been applied previously	**Go to Step 2**
2	Check if the measured value is significant	The measured value for ^{241}Am is above Decision Threshold. M_L = 900 Bq M_U = 1.4 Bq/day No contributions from past intakes.	In the given monitoring procedure the Decision Threshold is about 10 Bq for lung in vivo measurement and 0.5 mBq/l for urine activity concentration. **Go to Step 3**
3	Standard dose assessment	**Assessed Doses:** The initial lung and urine measurements evaluated by MONDAL3 resulted for E(50): **Lung: 500 mSv** **Urine: 780 mSv**	**Dose assessments using default parameters:** - inhalation[1] - single acute intake at the known date of intake - lung absorption type M - AMAD of 5 micrometer

			[1] RP188: *pure inhalation should be assumed as a default unless there is clear evidence for pure ingestion* **Go to Step 4**
4	Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit	Clearly E(50) > $1/SF^2$ mSv	RP188: … *if E(50)·* SF^2 *in Eq. E.6 is greater than 1 mSv, proceed to the next step.* **Go to Step 5**
5	Confirm assumption and findings related to exposure scenario	>4 lung and >3 urine monitoring data are available within 60 days range of time.	RP188: *It is recommended to confirm the assumptions/findings already adopted when the single measurement was interpreted, by performing further special monitoring measurements. For example, the same type of measurement could be repeated at short intervals, and/or different type(s) of measurements could be performed.* *After an incident, additional bioassay measurements are usually required to confirm the contamination scenario. The number of measurements required to confirm an unexpected exposure should be evaluated on the basis of the assessed dose E(50) using Tables C.6 and C.7 of* ***Chapter C****.* **Go to Step 6**
6	Check if the evaluated dose potentially exceeds the annual dose limit	The monitored data clearly indicated that the 20 mSv annual dose limit will be exceeded.	RP188: *If the analysis indicates that the annual dose limit may potentially be exceeded, it is recommended here that a more sophisticated analysis should be performed with the help of an expert. It is recommended that this more sophisticated analysis should follow the IDEAS Guidelines. In such cases the minimum number of measurements required is given in the columns of Tables C.6 and C.7 for E > 1 mSv.* **Go to IDEAS Stage 4**

Table 8-5: adapted from IDEAS Guidelines (Version 2): Stage 4

Step	Indication	Result	Notes
4.1	Pure inhalation	No evidence of pure inhalation	Case Description: *It turned out that some of the body surfaces and clothes are also contaminated.* **Go to IDEAS 4.2**
4.2	Pure ingestion	No evidence of pure ingestion	Case Description: *Using profile scanning measurement it was found that the majority of contamination is located in the lung area.* **Go to IDEAS 4.3**
4.3	Inhalation *and* ingestion	Assume inhalation as default	RP188: *assume pure inhalation as default unless there is information to justify that a part of the intake is ingestion.* No information to justify intake by ingestion; therefore assume inhalation. **Go to IDEAS Stage 5**

Table 8-6: adapted from IDEAS Guidelines (Version 2): Stage 5

Step	Indication	Result	Notes
STAGE 5A	**Initial assessment with a priori parameter values**		
5.1	Measured data	Sufficient number of monitored data are available for both on lung and urine activities.	**Go to IDEAS 5.2**
5.2	Contributions from previous intakes	No previous intakes are expected	**Go to IDEAS 5.3**
5.3	*a priori* parameters	**Assigned parameters:** - single intake[1] - lung absorption type M[2] - AMAD of 5 micrometer[3]	[1] Intake time is known [2] RP188, ICRP and OIR: *Default Type M is recommended for use in the absence of specific information on which the exposure material can be assigned to an Absorption Type, e.g. if the form is unknown, or if the form is known but there is no information available on the absorption of that form from the respiratory tract.*

			[3] RP188 (ICRP) default **Go to IDEAS Step 5.4**
5.4	Time of intake	Time of intake is known	 **Go to IDEAS Step 5.5**
5.5/5.6	Calculate dose with *a priori* parameters	Calculated dose is much higher than 1 mSv	Data have been given in previous steps. **Go to Stage 5B**
STAGE 5B	**Exposure related parameters**		
5.7	Sufficient relevant data	There are altogether 21 relevant lung activity data available however it cannot be excluded entirely that body surface contamination contributed to the first two measured values. It is also assumed that DTPA treatment does not alter the biokinetic behaviour of the respiratory tract. Consequently these data can be used for the assessment of Real Intake. At the first period 6 relevant urine activity data are available that are within the time range of 60 days and without the influence of DTPA treatment, however they are unevenly distributed covering only 9 days within the 60 days period. These data can be used for the assessment of Real Intake. During the time period of the DTPA decorporation treatment, 30 additionally monitored data are available from which the so-called "unaffected" data can be selected for the assessment of Apparent Intake and Committed Effective Dose.	IDEAS Guidelines: In the given level of expected doses due to ^{241}Am the minimum number of required monitored data should be 4 for lung and 3 for urine, with the conditions: *The monitoring data should cover a time range of 60 d;* As for the rough data the IDEAS statement are considered: *To identify outliers the following statistical test is proposed. A measurement value M(t) is an outlier if it is more than a factor of SF[3] away from the trend of the other data.* DTPA decorporation therapy has been applied, therefore only those urine activity data are selected for the evaluation procedure that are not influenced by the treatment. RP188: *To establish baseline excretion values (i.e. in the absence of decorporation), it is preferable to have bioassay measurements that are not influenced by the therapy, i.e. measurements before the start of the therapy or at least 3 weeks after the last treatment [SFMT 2011].* Monitored results indicated to apply more than 30 days waiting time after the last treatment. This resulted altogether 11 monitored urine data (6 before and 5

		Deriving applicable urine data measured during the DTPA administration period by applying an "enhancement factor" are not relevant for the intake and dose assessment because in this case no measured data fits to the requirements given in the RP188 approach.	during the therapy) that can be used for the evaluation out of the 36 data provided. RP188 introduced the term of „Apparent Intake" in the following way: *The IDEAS Guidelines [EURADOS 2013] make a recommendation based on [Jech 1972] to use only data collected later than 20 days after the end of therapy. A baseline excretion may then be established that corresponds to an "apparent intake", which is equivalent to the real intake minus the activity removed by the therapy. ICRP biokinetic and dosimetric models could be applied to calculate the apparent intake and subsequently the dose.* According to RP188 the individual and case specific "action" or "enhancement factor" can be applied when urine data are available on two consecutive days: just before and after the DTPA administration, with the following additional condition: *This action factor is only valid if the DTPA administrations are separated by at least 2 days.* As for the uncertainty of data the IDEAS suggested as B Type Scattering Factor (SF_B) for Lung: 1.25 for Urine: 1.6 has been considered to be attempted to get acceptable fit. **Go to IDEAS Step 5.8**
5.8	Time of intake	The time of intake is known	**Go to IDEAS Step 5.9**
5.9	Effective AMAD	Early lung and faeces data are not available, therefore Effective AMAD as it is defined in IDEAS Guidelines is not applicable in this case.	Effective AMAD according to the definition given in the IDEAS Guidelines: *If the cumulative faecal excretion over the first few days, and a measurement on which the initial lung deposit can be estimated are available, then an estimate can be made of the effective AMAD (Step 5.10).* **Go to Step 5.11**

<table>
<tr><td>5.11</td><td>Assessment of dose by fitting of the absorption type</td><td>Goodness of fit is not acceptable either the ICRP 66 or ICRP 130 recommended default parameters of M absorption type has been applied.</td><td>
<table>
<tr><th colspan="4">HRTM Absorption type M</th></tr>
<tr><td></td><td></td><td colspan="2">d^{-1}</td></tr>
<tr><td></td><td>f_r</td><td>s_r</td><td>s_s</td></tr>
<tr><td>ICRP 66</td><td>0.1</td><td>100</td><td>0.005</td></tr>
<tr><td>ICRP 130</td><td>0.2</td><td>3</td><td>0.005</td></tr>
</table>
OIR-Part 4 (Am draft):

Default Type M is recommended for use in the absence of specific information on which the exposure material can be assigned to an Absorption Type, e.g. if the form is unknown, or if the form is known but there is no information available on the absorption of that form from the respiratory tract.

Go to Step 5.13</td></tr>
<tr><td>5.13</td><td>Assessment of dose by fitting of the mixture of default absorption types (F, M, S).</td><td>Assessments of dose by fitting of a mixture of default absorption types (F, M, S) were not successful if simultaneous fitting of all relevant lung and urine bioassay data are considered.</td><td>IDEAS:

It is recommended, in cases where multiple types of bioassay data sets are available, that the intake and dose are assessed by fitting predicted values to the different types of data simultaneously.

Go to Stage 5C, Step 5.15</td></tr>
<tr><td>STAGE 5C</td><td colspan="3">Advanced evaluation</td></tr>
<tr><td>5.15</td><td>Goodness of fit</td><td>Goodness of fit is not acceptable;

As alternative approach an acceptable goodness of fit will be attempted by variation of the HRTM absorption parameters.</td><td>IDEAS:

In this stage, an advanced evaluation is carried out. It applies to cases where there are comprehensive data available. The fundamental approach is that the model parameter values are adjusted systematically, in a specific order, until the goodness of fit is acceptable.

Go to Step 5.16</td></tr>
</table>

5.16	Determine specific HRTM absorption parameters and estimate intake and dose		RP188 (Annex 1), OIR-Part 4 (Am draft) Recommended defaults

HRTM Absorption type M

		d^{-1}			d^{-1}
	f_r	s_r	s_s	f_b	s_b
ICRP 66	0.1	100	0.005		
ICRP 130	0.2	3	0.005		
OIR (draft for Am) Oxide, Chloride	0.2	0.4	0.005	0,002	0
OIR (draft for Am) Nitrate	0.6	0.4	0.005	0,002	0

There are two main points to be considered simultaneously in finding the best fit

- the better the fit the higher the p value above 0.05
- in the fitting procedure the HRTM absorption parameters should not alter very much from the default values

IDEAS: *Determine specific HRTM absorption parameter values: For materials that are moderately to very insoluble (typically absorption Types M or S), determine specific values for f_r and s_s by fitting f_r, s_s and intake to the data with s_r fixed at the value recommended in the ICRP OIR Document or in the ICRP Publication 68. For most materials there is no evidence for binding to the respiratory tract so the bound fraction f_b is taken to be zero. However, if relevant values of s_r and/or of f_b and s_b have been determined from in vivo experimental data then use these values.*

IDEAS: *The fit is acceptable then the estimated intake is taken as the best estimate and the committed equivalent doses to all organs and effective dose are calculated with the same model parameter values that were assumed for the assessment of intake.*

			OIR-Part 4 draft for Am: *…absorption parameter values for the bound state based on plutonium are applied in this document to the transplutonium elements for radiation protection purposes.* *…It is assumed that for americium a bound fraction $f_b = 0.002$ with $s_b = 0\ d^{-1}$ is applied throughout the respiratory tract except in the ET_1 region. The values of s_r for Type F, M and S forms of americium ($0.4\ d^{-1}$) are element-specific.* ICRP Publ. 130, OIR-Part 1: *For a radionuclide that is transferred from the respiratory tract to the alimentary tract, the default f_A value is determined as the product of f_r for the absorption type and the f_A value for soluble forms of the element.* **All calculations about intake and CED were obtained by using the IMBA Professional software.** **Discussion:** **Assuming ICRP Publ. 66 HRTM** Since the assessment depends very much on whether the first two lung activity measurements are considered in the evaluation or not, and since it depends also on the assessor's judgement, both assumptions are considered here. Assessment **A** considers 21, while **B** 19 lung activity data. ***Comments to Assessment No.1/A:*** The ICRP 66 HRTM default absorption parameters are: f_r :0.1 s_r 100 d^{-1} s_s: 0.005 d^{-1}
		Assuming ICRP Publ. 66 HRTM ***Parameters for Assessment No.1/A:*** Number of data: Lung:21, Urine:11 AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.7 f_r :0.2 s_r 100 d^{-1} s_s: 0.004 d^{-1} f_1: 0.0005 Probability: 0.056	

		Goodness of fit is acceptable: **Intake: 1.377 E+04 Bq** **E(50): 497 mSv** ---------- *Parameters for Assessment No.1/B:* Number of data: Lung:19, Urine:11 AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.6 f_r :0.2 s_r 100 d^{-1} s_s: 0.004 d^{-1} f_1: 0.0005 Probability: 0.185 *Goodness of fit is acceptable:* **Intake: 1.265 E+04 Bq** **E(50): 456 mSv** ========== **Assuming ICRP Publ. 130, OIR-Part 1 revised HRTM** *Parameters for Assessment No. 2/A:* Number of data: Lung:21, Urine:11	s_r rapid absorption rate was kept as default but its fraction f_r and the slow rate s_s have been changed in order to obtain an acceptable fit. This requirement could only be fulfilled assuming 5 µm AMAD, if the B type Scattering Factor for urine measurements $SF_{B,U}$ had to be increased to 1.7 from the default of 1.6. Though an acceptable fit could be achieved with only slight differences in absorption parameters but with just above the probability criteria of >0.05. *No.1/B:* Much better fits with the same absorption parameter values could be achieved with 19 data when the first two lung data have been excluded from the fitting process. In this way better fit was obtained even with the default scattering factor of $SF_{B,U}$: 1.6 Such changes in the number of lung data resulted in slight changes in the intake and E(50) estimations. Specifically, excluding the first two measurements, the obtained intake and dose values were found to be a bit lower compare to those received using the full set of data, consistent with the fact that the first measurements could be biased due to external contamination. ========== **Assuming ICRP Publ. 130, OIR-Part 1, revised HRTM** The ICRP 130 HRTM default absorption parameters are: f_r :0.2 s_r 3 d^{-1} s_s: 0.005 d^{-1}

		AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.7 f_r :0.46 s_r 3 d^{-1} s_s: 0.004 d^{-1} f_A: 0.00023 Probability: 0.059 *Goodness of fit is acceptable:* **Intake: 2.037 E+04 Bq** **E(50): 498 mSv** --- *Parameters for Assessment No.2/B:* Number of data: Lung:19, Urine:11 AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.6 f_r : 0.46 s_r : 3 d^{-1} s_s: 0.004 d^{-1} f_A: 0.00023 Probability: 0.198 *Goodness of fit is acceptable* **Intake: 1.868 E+04 Bq** **E(50): 456 mSv**	The ICRP 130 says about the HATM total absorption parameter of f_A: For a radionuclide that is transferred from the respiratory tract to the alimentary tract, the default f_A value is determined as the product of f_r for the absorption type and the f_A value for soluble forms of the element. *Comments to Assessment No. 2/A:* In this case the revised HRTM absorption parameters have been used in the fitting process. Here again the s_r default value of 3 d^{-1} was kept as fixed value and f_r together with s_s had to be changed in order to obtain an acceptable fit. It turned out that again a Scattering Factor of $SF_{B,U}$ = 1.7 had to be assumed for the good fit considering 21 lung data that gave a probability value just above the defined 0.05 criteria. According to the revised ICRP recommendation the Alimentary tract transfer factor f_A has been calculated as the product of the f_r and f_1 fractions however this did not influence the fitting process significantly. *Comments to Assessment No.2/B:* In this approach the respiratory absorption parameters were selected as in the assessment No.2/A only the first two lung data have been excluded from the fit. As for the results the fit showed a good probability of 0.198. When comparing the calculated intakes received by the ICRP 66 and ICRP 130 recommended HRTM models, remarkable increase can be observed while the appropriate E(50) values are practically the same. It has to be mentioned that the good agreement in dose data is surprising considering the differences in the absorption parameters used in the two models.

		==========	==========
		Assuming OIR-Part 4, (draft) **Am specific revised HRTM**	**Assuming OIR-Part 4, (draft)** **Am specific revised HRTM**
			In order to complete the investigation of the case, the dose assessment procedure has been continued by applying also the recent draft of the ICRP recommendation, OIR-Part 4, under preparation. This assessment is out of the strict scope of the present intercomparison exercise however it will be very instructive and informative on the future trends.
			In this OIR report material-specific absorption parameters (dissolution and uptake) are used for different compounds of Am as it has already been given in a previously presented table. Now the following values for this revised HRTM and HATM absorption parameters have been considered as defaults: f_r : 0.2 s_r : 0.4 d^{-1} s_s: 0.005 d^{-1} f_b : 0.002 s_b : 0 d^{-1} f_A: 0.00017
		Parameters for Assessment No.3/A: Number of data: Lung:21, Urine:11 AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.6 f_r : 0.35 s_r : 0.2 d^{-1}	***Comments to Assessment No.3/A:*** In this approach the same procedure has been followed as described in the previously mentioned four assessments given under No.1/A- No.2/B . Now the probability criteria could not be achieved when fixing the parameter s_r in the default value of 0.4 d^{-1}. No parameter combination could lead to a fit that met to the probability criteria even assuming the

		s_s: 0.004 d^{-1} f_b : 0.002 s_b : 0 d^{-1} f_A: 0.00017 Probability: 0.198 *Goodness of fit is acceptable* **Intake: 1.677 E+04 Bq** **E(50): 389 mSv** ---------- *Parameters for Assessment No.3/B:* Number of data: Lung:19, Urine:11 AMAD: 5 µm $SF_{B,L}$: 1.25 $SF_{B,U}$: 1.6 f_r : 0.35 s_r : 0.2 d^{-1} s_s: 0.004 d^{-1} f_b : 0.002 s_b : 0 d^{-1} f_A : 0.00017 Probability: 0.582 *Goodness of fit is acceptable* **Intake: 1.553 E+04 Bq** **E(50): 360 mSv** **ASSESSMENT TERMINATES**	scattering factor for urine measurements as $SF_{B,U}$= 1.7, as in the previous assessments. However, a successful fit was achieved by lowering the default to 0.2 d^{-1}. Actually, an even better fit with higher probability could be obtained when applying a lower value than 0.2 d^{-1}. Nevertheless 0.2 d^{-1} has been chosen for parameter s_r because no studies on animals resulted lower value than this, and the only human study provided the same 0.2 d^{-1} figure (B. Robinson et al. Health Phys. 45, 911 (1983). In this fitting process also a bound fraction of 0.002 has been applied with a bound absorption rate of s_b = 0, as suggested by the OIR-Part 4 draft for Am. Also here the f_A value has been derived as mentioned previously. The fit showed quite convincing probability, with a value of 0.198. Comparing the result for intakes and also for E(50) with those obtained in the previous four assessments (No.1/A- No.2/B) the results showed considerably lower values. *Comments to Assessment No. 3/B:* In this approach the same set of parameters has been used as in the previous one, including the parameters of the bound state. The fit with using 19 lung data out of the total 21 resulted also in this assessment having a much higher probability (0.582) than with 21 data (0.198), similar to the assessments based on the two previous ICRP recommended HRTM parameter sets. On investigating the effect of the applied bound state it turned out that the goodness of fit and the calculated intake are practically the same with or without assuming a bounded fraction whereas the obtained E(50) dose values are about 15% higher with bound state. It can be concluded from the measurements and from the dose assessment process of this accidental case, that it confirms rather a value of 0.2 d^{-1} as the rapid absorption rate than the default value of 0.4 d^{-1} suggested by the OIR-Part 4 draft for Am nuclides.

8.2.2 *Summary conclusions of the assessment*

In the whole dose assessment process for Case 4 the key-questions were how to select the relevant monitoring data and how to assume the uncertainties of these data, as expressed in scattering factors. The RP188 document and the IDEAS Guidelines provide guidance and suggestions on this subject; however, it ultimately depends on the judgement of the assessor.

It is noted that the Case Description included the following statement: "*At the very beginning considerable skin surface contamination was detected. In spite of the strong efforts in order to complete the decontamination it is possible, that in the first 1-2 weeks the skin contamination influenced the monitored lung activity data*." In reference to this statement the Recommended Assessments presented here led to the conclusion that a much better fit could be obtained by excluding the first two lung data from the fitting process. This is further justified because the remaining 19 relevant measurement data are sufficient to obtain a reliable result. Consequently the Recommended Assessments for Case 4 always refer to the results obtained by using the latter 19 lung measurements.

There is a considerable difference between the Recommended Assessment based either on the reference data of the ICRP Publ. 66 (ICRP 1994a) and ICRP Publ. 130 (ICRP 2015) on one hand, or on the OIR Part 4 (ICRP 2016b) on the other. It was found that the best fitting result could be obtained with the parameter values given in the last row of Table 8-7, as derived from OIR Part 4. Consequently this result can be regarded as the best Recommended estimate.

Table 8-7: Table of the "Recommended" assessments

ICRP Recomm.	Assess. No.	Number of data L/U	$SF_{B,L}$	$SF_{B,U}$	f_r	s_r d^{-1}	s_s d^{-1}	f_b	s_b d^{-1}	f_1/f_A	p	Intake kBq	E(50) mSv
ICRP 66	default parameters		1.25	1.6	0.1	100	0.005						
	1/A	21/11	1.25	1.7	0.2	100	0.004			0.0005	0.056	13.8	497
	1/B	19/11	1.25	1.6	0.2	100	0.004			0.0005	0.185	12.7	456
ICRP 130	default parameters		1.25	1.6	0.2	3	0.005			0.0001			
	2/A	21/11	1.25	1.7	0.46	3	0.004			0.00023	0.059	20.4	498
	2/B	19/11	1.25	1.6	0.46	3	0.004			0.00023	0.198	18.7	456
OIR-4 draft Am	default parameters		1.25	1.6	0.2	0.4	0.005			0.0001			
	3/A	21/11	1.25	1.6	0.35	0.2	0.004	0.002	0	0.00017	0.198	16.8	389
	3/B	19/11	1.25	1.6	0.35	0.2	0.004	0.002	0	0.00017	0.582	15.5	360

In all cases 5 µm AMAD value was assumed

This Recommended assessment is further supported by the following considerations: in principle, when calculating the real intake and, separately, the undisturbed apparent intake, the difference should be the total eliminated excess activity by urine due to the DTPA therapy. The total amount was estimated to be about 2 kBq, as given in the case description. According to the RP188 the definition for "apparent intake" is as follows: "*In principle, it corresponds to the real intake minus the activity removed from the body as a result of the therapy."* This should (probably) be corrected, since the DTPA administration affects only the activity retained in the boy, which is only a portion of the intake. For instance, in the present case of inhalation of 5 µm AMAD aerosol, the activity in the body accounts for 82 % of the original intake. Thus, an eliminated excess of 2 kBq corresponds to about 2.4 kBq in terms of intake. If the real intake is calculated using the 19 lung data plus the 6 early urine data, and the apparent intake considering the late 5 urine data, the results and the applied fitting parameters are given in the following Table 8-8.

Table 8-8 : Comparison of the real and apparent intake

OIR-4	Number of data L/U	$SF_{B,L}$	$SF_{B,U}$	f_r	s_r d^{-1}	s_s d^{-1}	f_b	s_b d^{-1}	f_1/f_A	p	Real Intake kBq	Apparent Intake kBq	E(50) mSv
	19/6	1.25	1.6	0.35	0.2	0.004	0.002	0	0.00017	0.293	15.74	-	365
	0/5	1.25	1.6	0.35	0.2	0.004	0.002	0	0.00017	0.877	-	13.86	321

In both cases 5 µm AMAD value was assumed

According to the results, summing up 2.4 kBq (the component of the "intake" eliminated by therapy) with 13.9 kBq (apparent intake) results in 16.3 kBq, which is reasonably close to the value of 15.7 kBq (real intake). The agreement is within 5 %, which justifies that this set of absorption parameters provides the best fit to the data. It means at the same time that the assumed dose reduction due to the DTPA therapy is about 12%.

A more critical issue is the selection of those relevant urine activity data that are not influenced by the DTPA treatment. It turned out that the minimum 20 days after the DTPA administration, as it is suggested by IDEAS Guidelines, is not sufficient in this case. Finally, 11 urine activity data were selected for the evaluation process. Another possible approach, namely to determine a DTPA "action" or "enhancement factor" in calculating the assumed case-specific non-disturbed values, was not followed because the timing of DTPA administration in relation with urine sampling does not meet the conditions of this method, as given in the RP188 and IDEAS documents.

8.3 Overall measurements statistics

8.3.1 *Estimates of Intake and Committed Effective Dose*

There were several misunderstandings in the submitted results in relation to the intentions of the intercomparison. These mostly related to the interpretation of the term "Best estimate". These have been cleared up by several letters so it is believed that, after corrections, all submitted results meet the requirements. The overall statistics for the solutions submitted are recorded in Table 8-9 and Table 8-10 for the final intake and the total committed effective dose respectively, as the best estimates irrespective whether the lung, the urine or both measured data were used for calculating the best estimate.

The Tables also indicate the three Recommended Solutions in order to determine the influence of the changes in the HRTM parameters of ICRP, as described in Section 8.2, together with the interval range of +/- a factor of three, which is considered to indicate the acceptable range of divergence.

Table 8-9: Overall statistics of solutions on Case4 submitted for estimates of final intake

Number of submissions	31
Quantity	Intake
Unit	Bq
Parameters excluding outliers	
GM	13663
GSD	1.419
Number of outliers	1
Parameters including outliers	
Min	6278
Max	39000
Ratio Max/Min	6.212
Robust mean (RM)	14574
Robust st. dev. (RSD)	5387
RSD / RM (%)	37.0
Recommended value (ICRP-66)	**12650**
Rec/3	4220
Rec*3	37950
Number of data less than Rec/3	0
Number of data greater than Rec*3	0
Recommended value (ICRP-130)	**18680**
Rec/3	6227
Rec*3	56040
Number of data less than Rec/3	0
Number of data greater than Rec*3	0
Recommended value (OIR-4)	**15530**
Rec/3	5177
Rec*3	46590
Number of data less than Rec/3	0
Number of data greater than Rec*3	0

Table 8-10: Overall statistics of solutions on Case4 submitted for best estimates of committed effective dose

Number of submissions	31
Quantity	E(50)
Unit	mSv
Parameters excluding outliers	
GM	381.6
GSD	1.426
Number of outliers	1
Parameters including outliers	
Min	81
Max	880
Ratio Max/Min	10.86
Robust mean (RM)	388.1
Robust st. dev. (RSD)	145.5
RSD / RM (%)	37.5
Recommended value (ICRP-66)	**456**
Rec/3	152
Rec*3	1368
Number of data less than Rec/3	1
Number of data greater than Rec*3	0
Recommended value (ICRP-130)	**456**
Rec/3	152
Rec*3	1368
Number of data less than Rec/3	1
Number of data greater than Rec*3	0
Recommended value (OIR-4)	**360**
Rec/3	120
Rec*3	1080
Number of data less than Rec/3	1
Number of data greater than Rec*3	0

The frequency distribution of the submitted results for final intakes is shown in Figure 8-1. Values of the Robust Mean as well as the three intake values resulting from the Recommended assessments are also indicated on the Figure 8-1. The term 'final' or 'best' intake means the estimated intake from which the best dose estimate has been calculated, irrespective whether they were considered as real or apparent intake.

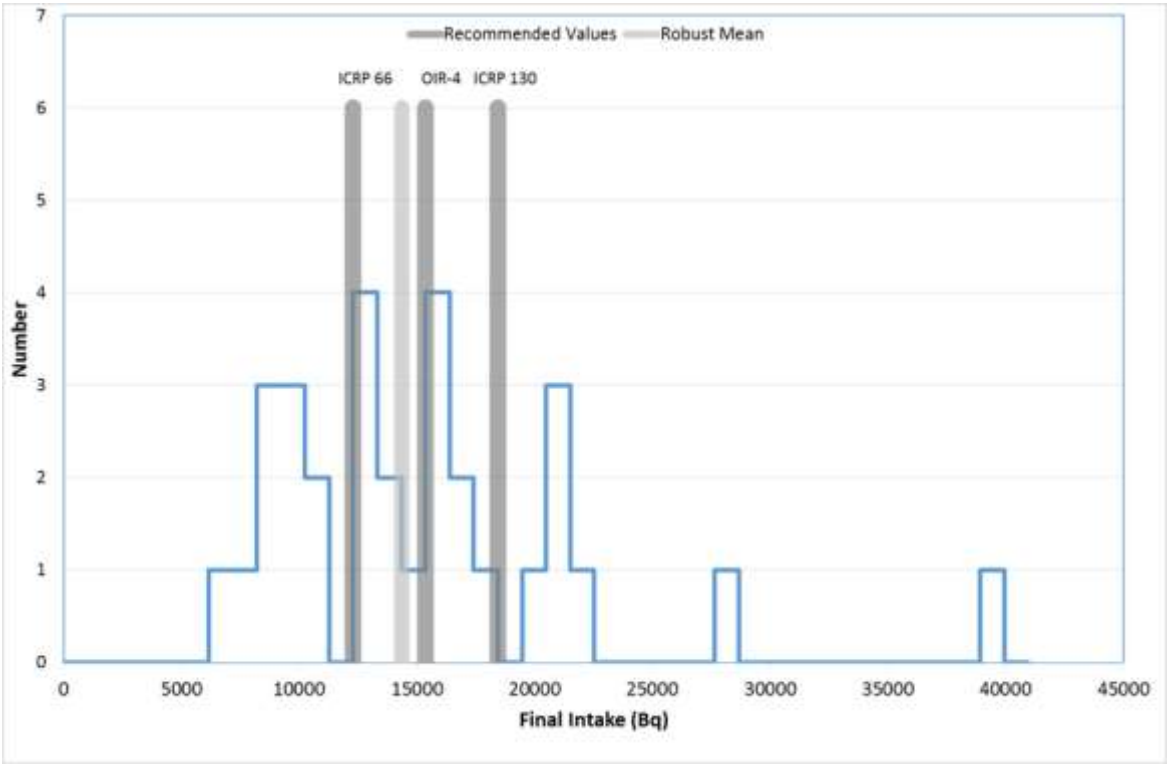


Figure 8-1: Case 4 frequency distribution of the estimates of final intake (Bq).

The submitted values on estimated best intake according to the participants, indicated by their PID number, are illustrated in a histogram in Figure 8-2, where the values are compared with the Robust Mean.

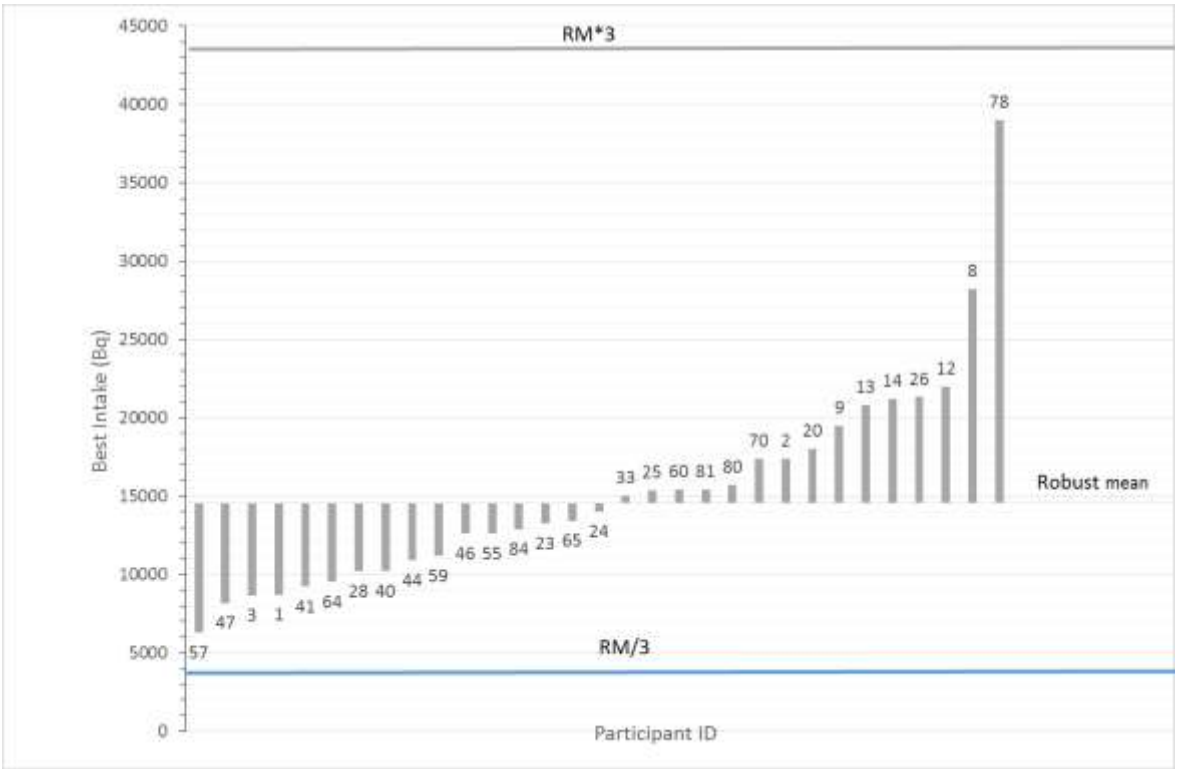


Figure 8-2: Case 4 histogram on the submitted best intake estimates by participants in comparison with the Robust Mean as reference value. (Bq).

A similar frequency distribution is displayed in Figure 8-3, where the submitted values of committed effective dose as best estimates are shown.

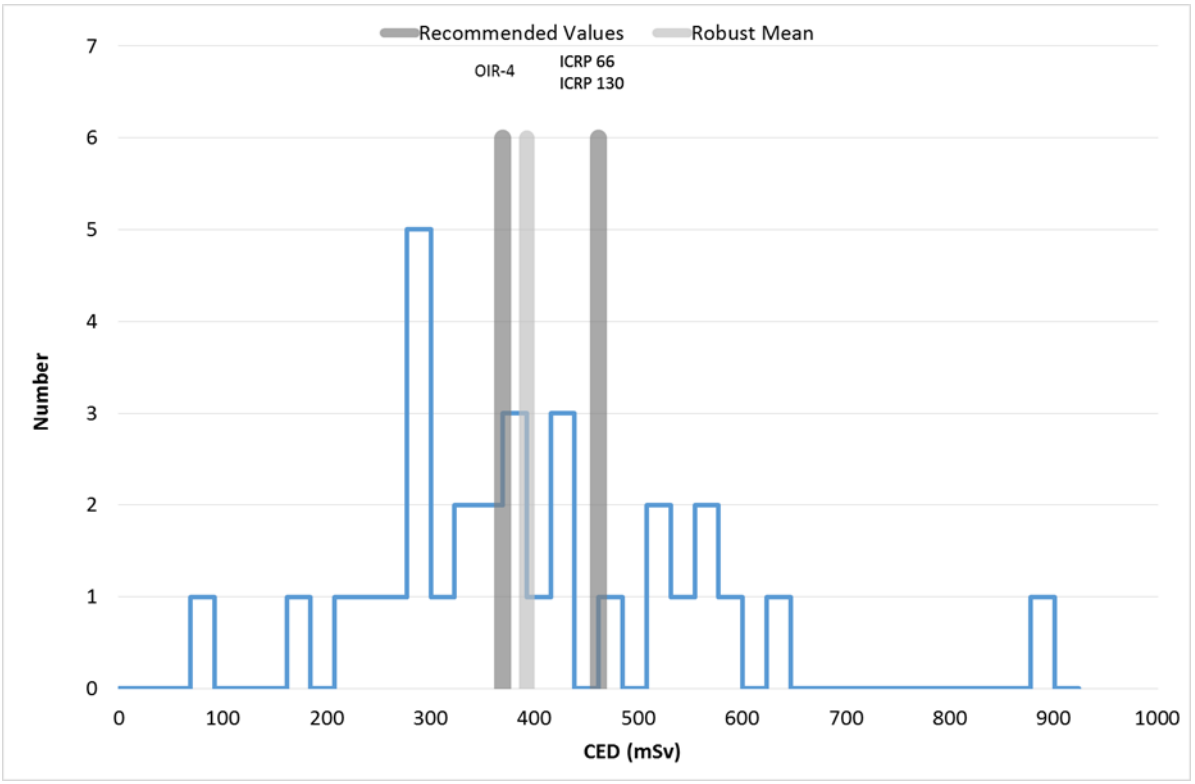


Figure 8-3: Case 4 frequency distribution of best estimates of committed effective dose (mSv)

The submitted best estimates on the committed effective dose are shown in Figure 8-4 according to their values on a histogram, indicating also the PID numbers of the participants.

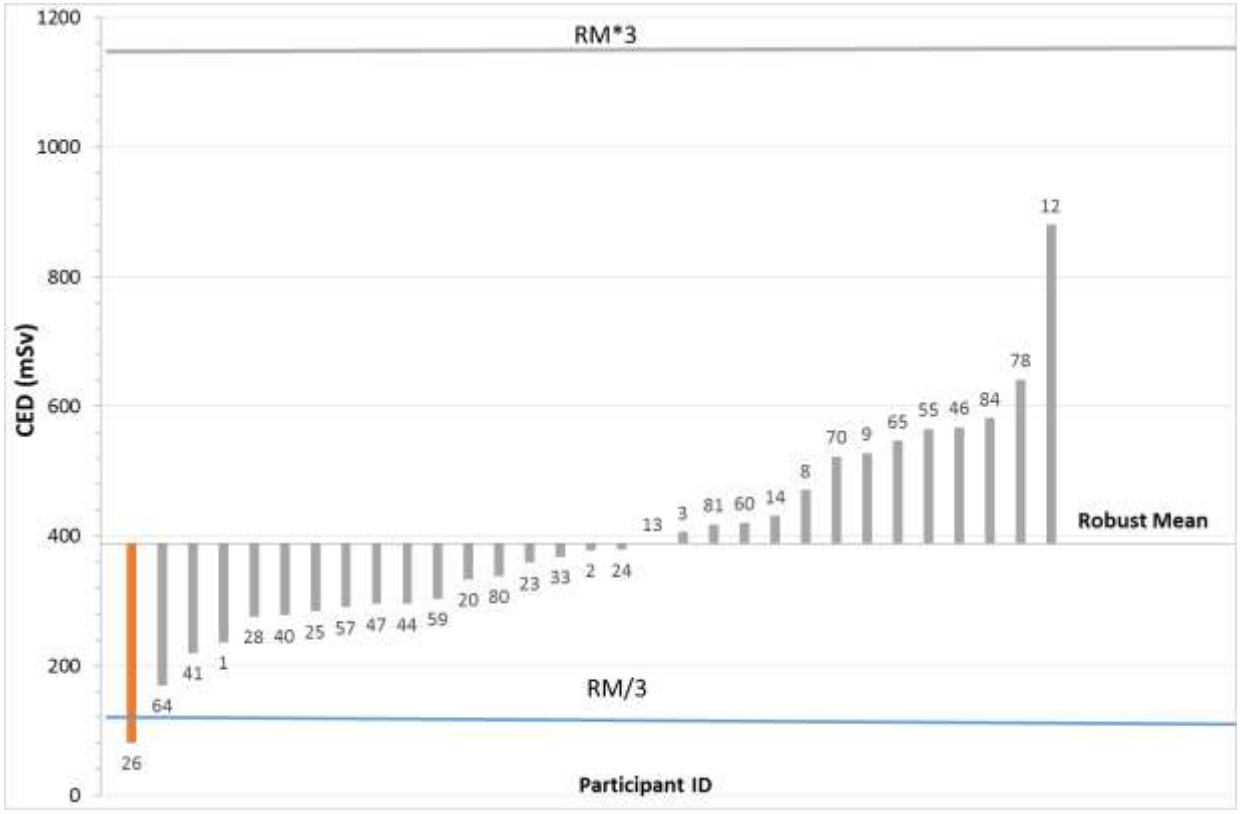


Figure 8-4: Case 4 histogram on the submitted best estimates of committed effective dose by participants in comparison with the Robust Mean as reference value (mSv).Outlier is indicated in red.

8.3.2 *Estimates of Dose Coefficient*

An interesting frequency distribution can be obtained when the dose coefficients, as used for final estimates, are compared with the ICRP Publ. 119 (ICRP 2012) reference value of 2.7 E-05 Sv/Bq for inhalation by workers, (5 µm AMAD) and for HRTM absorption type M. These values, together with dose coefficient values calculated from the IMBA software and used in the Recommended assessment, are shown in the Figure 8-5.

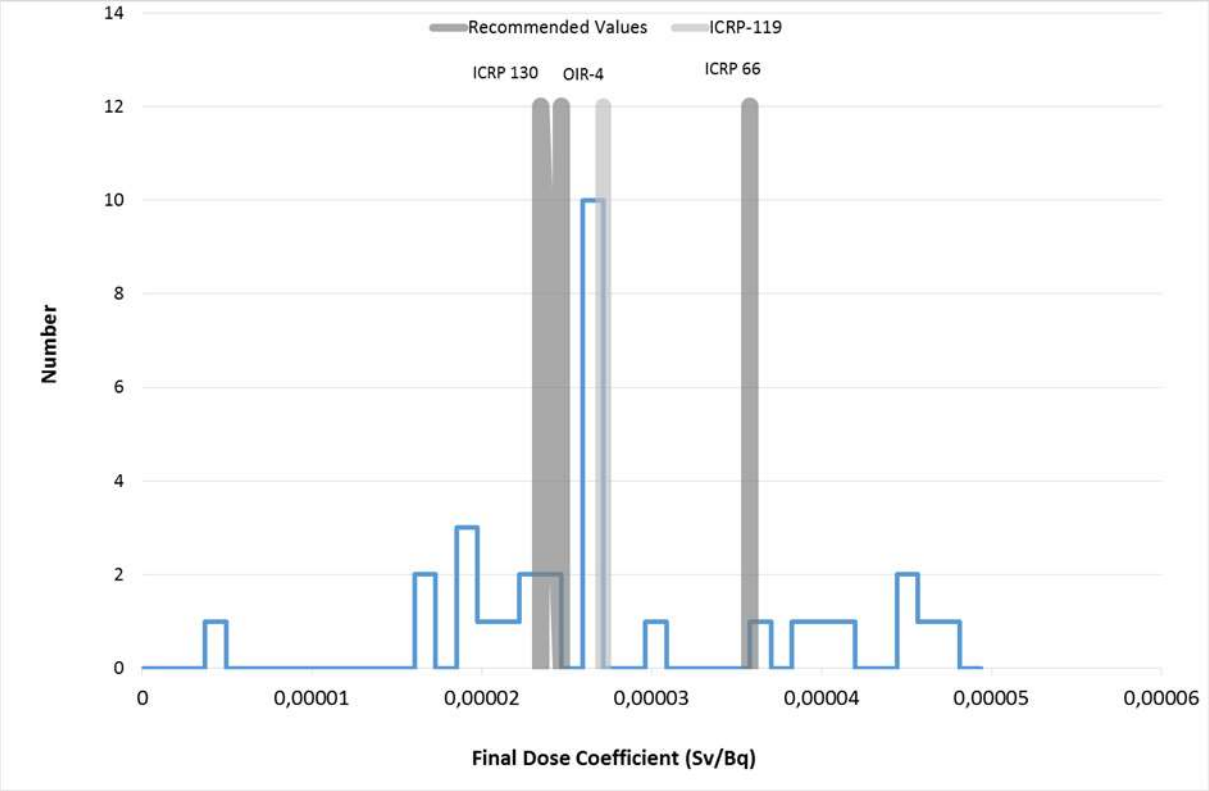


Figure 8-5: Case 4 frequency distribution of the final dose coefficients submitted by the participants.

Another interpretation of the large spread of the applied dose coefficients is illustrated in a scatter plot on Figure 8-6, which displays the values of the submitted final intakes versus the corresponding best dose estimates. It is noted that the regression line provides a very similar value for dose coefficient (2.36 E-05 Sv/Bq) as that which is obtained in the Recommended assessment based on ICRP Publ. 130 (ICRP 2015) (OIR-1) (2.44 E-05 Sv/Bq) and on OIR-4 (ICRP 2016b) (2.32 E-05 Sv/Bq)), and does not differ very much from the value given in ICRP Publ. 119 (ICRP 2012) (2.7 E-05 Sv/Bq).

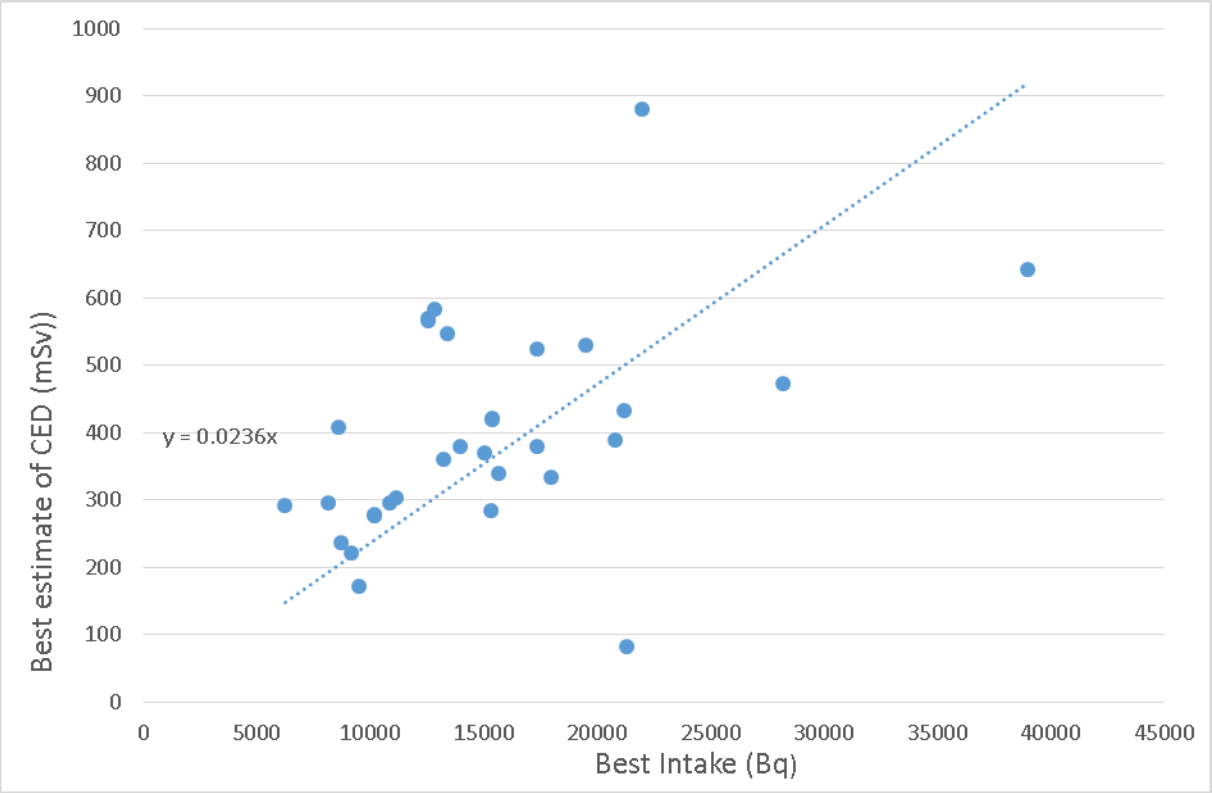


Figure 8-6: Case 4 scatter plot of best (final) intake estimate v. best estimate of committed effective dose.

In the Figure 8-7 the submitted values on final dose coefficients are presented in histograms indicating also the PID numbers of the participants. The X axis corresponds to the dose coefficient recommended by the ICRP in the Publ. 119. It is seen from the figure that about one third of participants used a value very close to the ICRP recommendation.

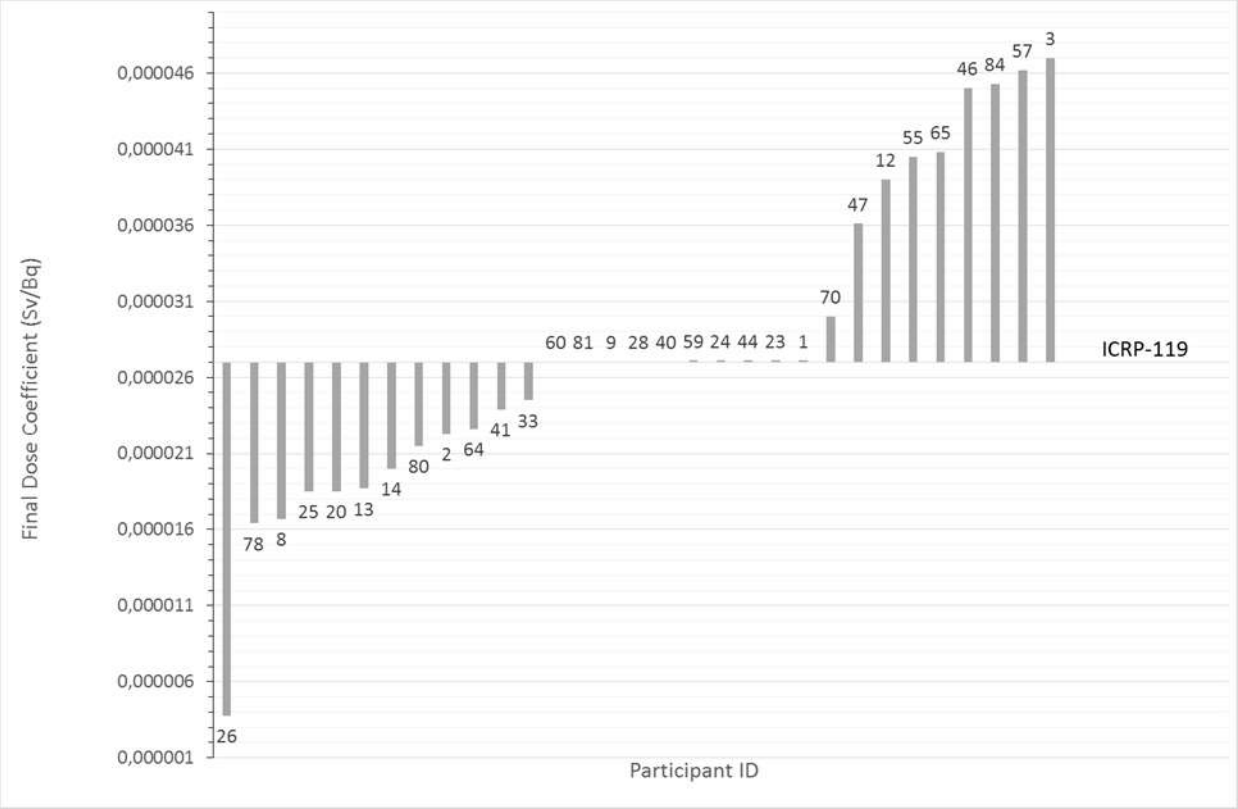


Figure 8-7: Case 4 histogram on the submitted values of finally used dose coefficient according to the participants in comparison with the ICRP Publ. 119 recommended value of 2.7 E-05 Sv/Bq.

8.3.3 *Estimates of Dose Coefficient*

The RP188 definition on "apparent intake" is given as follows:

"The *intake* that is consistent with the daily excretion observed after the effect of a *decorporation* therapy has vanished. In principle, it corresponds to the real intake minus the *activity* removed from the body as result of the therapy."

In Chapter E5 of RP188 the definition is completed with the following text:

"The IDEAS Guidelines [EURADOS 2013] make a recommendation based on [Jech 1972] to use only data collected later than 20 days after the end of therapy. A baseline excretion may then be established that corresponds to an "apparent intake", which is equivalent to the real intake minus the activity removed by the therapy. ICRP biokinetic and dosimetric models could be applied to calculate the apparent intake and subsequently the dose."

In the description of Case 4 a total of 36 urine data were given, from which the participants had to select data that are not influenced by the DTPA therapy. The method of using an "enhancement

factor" in order to define the baseline excretion is not applicable since the timing of urine sampling and DTPA administration does not match the required conditions, as discussed in Section 8.2. Considering this fact, the baseline excretion can only be determined by the data that are surely not affected by the treatment. Consequently, only 11 measurements are available for further evaluation out of the total of 36; six of these data were measured before the DTPA administration, and five during the treatment in the later observation period. In principle, the real intake can be determined using the first six urine measurements and the lung data; while for the calculation of the baseline excretion and the "pure" apparent intake only the last five urine data are available. Since they are very late data with high uncertainties the determination of the apparent intake from these data alone becomes very uncertain. Results with higher values for apparent intake than for real intake cannot be explained. The spread of submitted results is demonstrated by the scatter plot in Figure 8-8, showing the results of 18 participants out of the 31, who provided values for both real and apparent intakes.

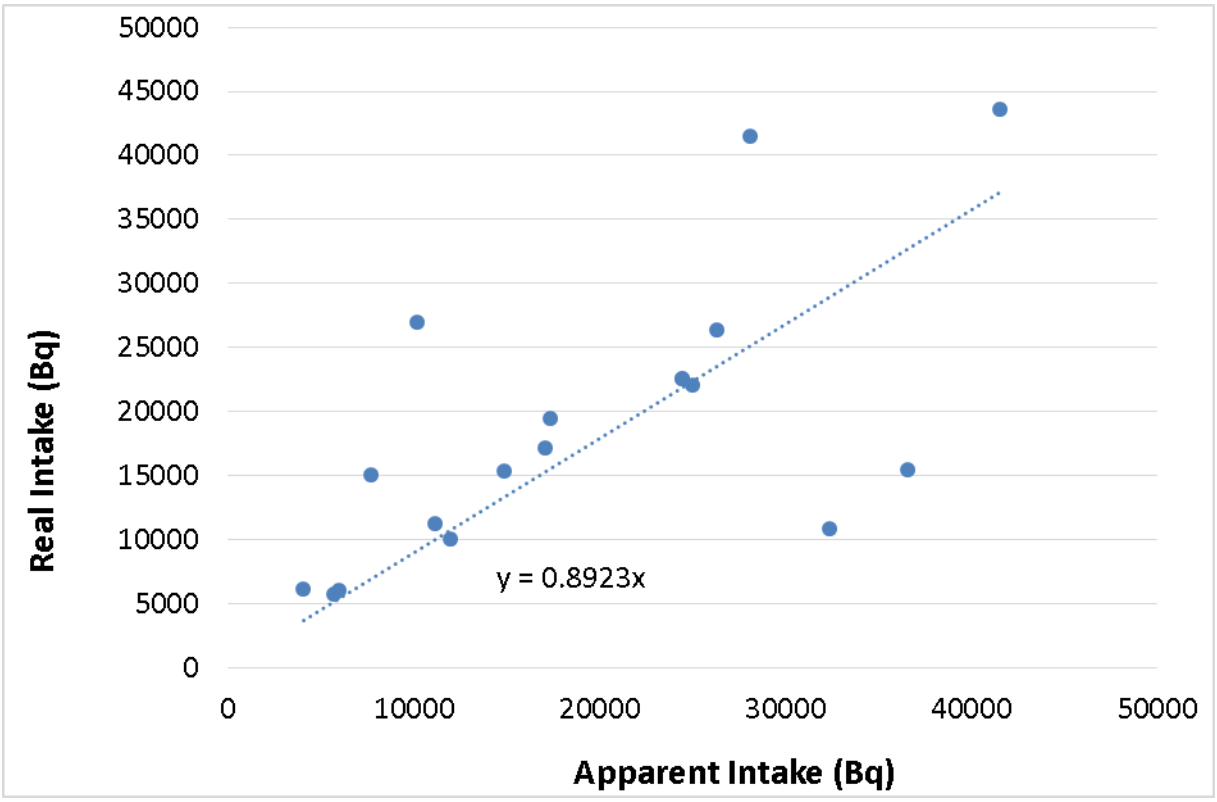


Figure 8-8: Case 4 scatter plot of apparent intake v. real intake.

8.4 Observations and discussion on selected aspects

In Case 4, where more assumptions were required for the evaluation, further comments would have been needed to understand the way of thinking and the assumptions made by the participants in the evaluation process. Unfortunately there was no specific place for comments in the submission form; some participants chose to use labels to annotate the form, or comments were provided by subsequent correspondence with the organisers.

Another aspect that was missing in the design of the submission form was that it did not allow for the recording of a mix of three HRTM absorption types (only two) when deriving the best fit. In this case the organisers assumed that if the sum of the percentages of two absorption types did not give 100%, than the difference is attributed to the third (unrecorded) type.

8.4.1 *Data of measurements*

The selection of measured data is one of the most important parts in the evaluation process, and inevitably involves subjective elements, as is seen in the summary tables below.

i) Lung activity data

In the case description, altogether 21 data were given together with their statistical uncertainties. Since it has been also commented that *"it is possible, that in the first one to two weeks the skin contamination influenced the monitored lung activity data"* the consideration to use the first two data in the fitting process depended on the assessor's judgement. But it turned out from the submitted results that there were other considerations as well.

Table 8-11: Frequency distribution of the number of lung activity data used for dose assessment.

Number of lung data used	21	19	16	13	12	7	6	5	2
Number of evaluations	10	11	1	1	1	3	1	1	1

It is seen that about one third of the participants used all the data provided, while another third disregarded the first two data and considered only 19 data. Nine participants used only 16 data or (substantially) less. One participant submitted 21 data in the table with appropriate dates, but the values of the activities quoted differed from those given in the case description. The participants that used less than 19 measured data applied either the early data or just those measured in the later period. One participant did not give any data so left the table empty.

ii) Urine activity data

The case description provided 36 data on daily excreted urine activities collected over the two-year observation period; however, due to the DTPA decorporation therapy, most of the data could not be used as relevant for the dose assessment procedure. Unfortunately the time of urine sampling and the time of DTPA administration was not properly coordinated from the dose assessment point of view. RP188 recommends:

" In the case of DTPA treatment, the plutonium intake may be estimated from urine measurements obtained more than 20 days after DTPA administration and/or from urine excretion measured on the day following DTPA administration after correction with a DTPA enhancement factor. This factor may be taken to have a nominal value of 50 or adjusted to an individual-specific value determined after a therapeutic window. The application of the enhancement factor is only valid if the DTPA administrations are separated at least by 2 days."

For this reason only those data that are supposed to be unaffected by the treatment can be used. One possible approach could have been to determine the baseline excretion by applying the enhancement or action factor, but the conditions for its use are not fulfilled in the given case: only one data might be considered to meet the this requirement. A more realistic way for defining the

baseline excretion is to consider those data that have been measured much later after the DTPA administration. RP188 recommends *"more than 20 days"*, but the measured dataset showed that this time should be increased to about 30 days in order to achieve the baseline excretion. Since the assumption of this time gap depends very much on the subjective judgements of the participants, there are wide variations in the number of urine activity data that have been used for dose evaluation.

Table 8-12: Frequency distribution of the number of urine activity data used for dose assessment.

Number of urine data used	22	20	19	18	16	15	13	12	11	10	9	7	6	5
Number of evaluations	1	1	1	1	3	2	1	2	8	1	1	2	5	1

As it is seen in Table 8-12 two maxima can be observed in the use of urine data: eight participants selected 11 measured data and five estimations are based on 6 data. The former are characteristic for determining the apparent intake, and the latter for determining the real intake.

8.4.2 *Data on Scattering Factor type B*

Another important factor in the course of dose assessment is the applied uncertainties connected to the monitoring data. When fitting the ICRP biokinetic models to the data the values of uncertainties are represented by scattering factors that are defined by the IDEAS Guidelines and adopted by the RP188 document.

According to RP188 recommendations:

"*For statistical tests in the dose assessment procedure and to evaluate its contribution to overall uncertainty in assessed dose, the measurement uncertainty should be expressed by a scattering factor (SF). The values of SF from Tables 4.8 and 4.10 of the IDEAS Guidelines [EURADOS 2013] should be adopted."*

The referenced tables from the IDEAS Guidelines are as follows:

Table 8-13: Typical values for the total type A and type B log-normal uncertainty for in vivo measurements

Uncertainty type	Scattering factor SF		
	Low photon energy E < 20 keV	Intermediate photon energy 20 keV < E < 100 keV	High photon energy E > 100 keV
Total type A	1.5	1.3	1.07
Total type B	2.06	1.25	1.15
Total	2.3	1.4	1.2

For ^{241}Am activity in the lung the typical default value for Scattering Factor type B is 1.25. The Scattering Factor type A has been derived from the measurements and not from the table. The next table summarises the distribution of SF_B values applied by the participants.

Table 8-14: Frequency distribution of B type Scattering Factors for lung data used for dose assessment.

SF_B for lung data	1.25	1.3	1.4	1.5	2	2.06	3
Number of evaluations	15	1	3	1	2	1	1

Unfortunately seven participants did not provided any data on the Scattering Factor used. As it is seen on the table, the typical default value of 1.25 has been predominantly used by the participants. It is difficult to explain the use of a special value of 2.06; and it has to be mentioned that the value of 3 is inexplicable high: using this SF factor in the fitting process would allow any kind of retention function to be fitted with a high statistical probability. On this respect IDEAS Guidelines has the following sentence:

"The χ^2 test uses the assumed uncertainties SF_i. If the assumed uncertainties are overestimated then χ_0^2 is too small and a bad fit is accepted."

Table 8-15: Typical values for the scattering factor SF for various types of *in-vitro* measurements from different studies.

Quantity	Scattering factor SF_B
True 24-hr urine	1.1
Activity concentration of ^{3}H (HTO) in urine	1.1
Simulated 24-hr urine, creatinine, volume or specific gravity normalised.	1.6 (1.3 - 1.8)
Spot urine sample	2.0
Faecal 24-hr sample	3 (2 - 4)
Faecal 72-hr sample	2 (1.5 – 2.2)

As written in the case description the urine data, in terms of daily excreted activities, have been derived from the activity concentrations normalised according to the volumes. Consequently the typical default B type Scattering Factor is 1.6, but can be within the range of 1.3-1.8. The following table summarises the submitted SF_B values for urine data, applied as uncertainties in the fitting process.

Table 8-16: Frequency distribution of B type Scattering Factors for urine data used for dose assessment.

SF_B for urine data	1.6	1.75	1.8	2	3
Number of evaluations	17	1	2	4	1

Six participants did not give any value. The table shows that the great majority of participants applied the typical SF_B value of 1.6 in the evaluations. The participant who submitted the unrealistic SF_B value of 3 for urine data also gave the same figure for the lung data.

8.4.3 *Data on HRTM absorption type and absorption parameters*

The IDEAS Guidelines say:

"The ICRP default absorption types for particulate materials: F (fast), M (moderate) and S (slow) each represent very wide ranges of absorption rates. There can be large differences between the actual absorption behaviour of a material and that assumed for the default to which it is assigned, which can greatly affect lung retention and urinary excretion. Evaluations are therefore made assuming each of the other default types available for that element. In each case a check is made on the Goodness of fit."

and in another place in the structured steps:

"Assessment of dose by fitting a mixture of absorption Types. This is an extension of Step 5.11, to give greater flexibility in fitting by considering a mixture of absorption Types.

There are sufficient relevant data available on lung retention and on daily urinary excretion to enable a detailed analysis for dose assessment. According to IDEAS Guidelines: "*It is recommended, in cases where multiple types of bioassay data sets are available, that the intake and dose are assessed by fitting predicted values to the different types of data simultaneously."*

Considering the uncertainties in the physical and chemical characteristics of the contaminant, and the need of simultaneous fitting, it seemed necessary to apply a mix of default absorption types in order to obtain an acceptable fit. For this reason the submission form was designed to allow the possibility to give an arbitrary mixture of two default absorption types. However, it turned out that results have been submitted where all three F, M and S default absorption types were recorded. Altogether, 20 participants have chosen to use either a single or a mixture of absorption types as the method for determining the lung absorption characteristics.

Table 8-17: Frequency distribution of submitted HRTM Absorption Types used for dose assessment.

Absorption Type	M	F/M/S	F/M/S	F/M/S	F/M/S	F/M/S	F/M/S
Percent	100	2/98/0	89/0/11	26/54/20	0/74/26	0/86.4/13.6	0/95/5
Number of evaluations	13	1	1	2	1	1	1

The Table 8-17 shows that 13 participants out of the 20 could find an acceptable fit without making any changes in the absorption parameter values relevant to the absorption type M. This result assumes that all results submitted by these participants were obtained in a fitting process where the goodness of fit gave a probability value $p > 0.05$.

As previously mentioned, there was no place in the submission form for recording a third absorption type; therefore, in the case of two submissions, it was assumed that the value of the third missing percentage completes the given values to 100.

A complete evaluation of results, knowing the selected absorption types or their mixture (Table 3A in the submission form), is not feasible since eight participants have not provided the finally used figures in terms of absorption parameters, as required as input data in the applied software. The remaining 11 participants have chosen to find the acceptable fit by changing the HRTM absorption parameters. When doing this the following instructions of the IDEAS Guidelines had to be considered.

"Determine specific HRTM absorption parameter values: For materials that are moderately to very insoluble (typically absorption Types M or S), determine specific values for f_r and s_s by fitting f_r, s_s and intake to the data with s_r fixed at the value recommended in the ICRP OIR Document or in the ICRP Publication 68."

According to the recommendations, the task was to start with the default absorption parameters of M or S types (in our case rather M) and keeping the s_r rapid rate fixed while changing the rapid fraction f_r and s_s in order to get an acceptable fit. Now the question arises which ICRP publication should be regarded as the relevant reference. In the present intercomparison exercise the reference HRTM model described in the ICRP Publ. 66 was considered. However there are submitted results calculated using the unpublished OIR-4 draft document but no submitted assessment was based on the HRTM model parameters recommended by the ICRP Publ. 130 (OIR-1). The submitted lung absorption parameters are presented in Table 8-18.

Table 8-18: Submitted values of HRTM absorption parameters used for dose assessment.

Participant PID	f_r	s_r	s_s	Recommendation
2	0.54	0.47	0.0022	OIR-4 draft
3			0.012	?
13	0.8	0.02	0.0001	?
20	0.8	0.02	0.00001	?
26	0.26	100	0.0025	ICRP-66
41	0.05	100	0.004	ICRP-66
44	0.01	100	0.005	ICRP-66
47	0.2	0.4	0.005	OIR-4 draft
65	0.25		0.004	?
80	0.5	0.2	0.003	OIR-4 draft
84	0.3	100	0.0035	ICRP-66

One participant who used the OIR-4 draft for the evaluation indicated that the parameter for the bound state has also been applied: maybe the other two did the same. Looking at the submitted lung absorption parameter values in the table, the reason for the missing data for two participants cannot be explained. The question marks indicate that the original sources of these figures are unknown.

8.4.4 *Data on f_1 or f_A factors*

The great majority, 25 participants, indicated the use of the default value of 0.0005 for f_1, while two participants used the OIR-4 draft, and defined f_A at a value of 0.0001, according to the recommendation:

"For inhaled material deposited in the respiratory tract and subsequently cleared by particle transport to the alimentary tract, the default f_A values for inhaled materials are applied: i.e., the product of f_r for the absorption Type (or specific value where given) and the f_A value for ingested soluble forms of americium (5×10^{-4})."

This final f_A is derived from the default of 0.0005 and multiplied by the f_r, which is 0.2 when the default HRTM absorption fraction is taken. The remaining two participants declared the use of the default value but left the box empty; one did not give any answer to this question. The last one presented 0.005 for this parameter - which is probably a typing error.

8.4.5 *Data on AMAD values*

The information provided in the case description for AMAD value of the aerosol is not sufficient in order to define an *a priori* value; therefore the ICRP recommended default value should be used as it is given also in RP188 as follows: *"By default, inhalation of an aerosol with an AMAD of 5 μm is assumed for occupational exposures."*

The other option would have been to determine the effective AMAD which is defined by the IDEAS Guidelines:

"ICRP Supporting Guidance 3 (ICRP 2002b) showed that for a relatively insoluble (Type M or S) material inhaled by a Reference Worker, the ratio of cumulative faecal excretion over the first 3 days ($F_{1\text{-}3}$) to lung activity on day 3 (L_3) increased almost linearly with AMAD over the range 1 to 10 μm."

Since, unfortunately, there are not any faecal excretion data available then this is not an option. Another problem is that when strictly following the steps defined by the IDEAS Guidelines, at Step 5.9 if no data are available on "effective AMAD", there is no possibility to try to find a better fit by varying the value of AMAD. Consequently, after this step and strictly following the IDEAS procedure, there is no way to use a value other than the default 5 μm. Varying this value is possible, of course, using a software tool like IMBA, but this would deviate from the procedure.

The great majority of the participants (24) submitted 5 μm, the default value of AMAD. Seven participants indicated other values than this, as is shown on the Table 8-19:

Table 8-19: Submitted values of AMAD other than the default 5 μm used.

AMAD (μm)	0.5	1	9	10
Participant PID	3	12, 47	26	8, 25, 78,

It is interesting to note that someone found a better fit with lower AMAD values, and others with higher AMAD values than the default. Two participants have submitted 5 μm but indicated this as not a default, while one participant gave 1 μm as a default.

8.4.6 *Choosing the best estimate*

IDEAS clearly says:

"*It is recommended, in cases where multiple types of bioassay data sets are available, that the intake and dose are assessed by fitting predicted values to the different types of data simultaneously.*"

The great majority, altogether 23 participants, defined their results by simultaneous fitting both lung and urine data as the best dose estimate. Three believed their best assessment was obtained by using the lung data only; and, surprisingly, five participants thought that their estimation based on exclusively on urine data is the best. The latter results were unexpected since the uncertainties expressed in terms of the total Scattering Factor associated to the urine data were much higher than those given for lung activity measurement. In addition, the majority of urine data were disturbed due to the altered biokinetics caused by the DTPA therapy.

8.4.7 *Comparison between accredited and non-accredited institutions*

On the submission form one question related to the accreditation, namely: whether the institution the participant came from has some kind of accreditation, certificate, etc. in internal dosimetry that is relevant to the present intercomparison. From the intercomparison point of view in the evaluation process it has no importance. Even so, a rough comparison has been made based on calculating the Robust Mean of the final values of intake and dose. It is noted that 30 out of the 31 participants answered the question. As it is seen on the table below practically one half of the participants answered "yes" to the accreditation. Considering the broad spread of the final results no conclusions can be drawn from the figures obtained. This is illustrated also in the distribution chart for assessed Committed Effective Dose, Figure 8-9.

Table 8-20: Comparison of two subsets on final results according to whether an accredited or not accredited institution submitted their results.

	Not accredited 14 Participants		Accredited 16 Participants	
	RM	RSD	RM	RSD
Total Intake (Bq)	15433	7456	14980	4651
Best E(50) (mSv)	332	81	444	155

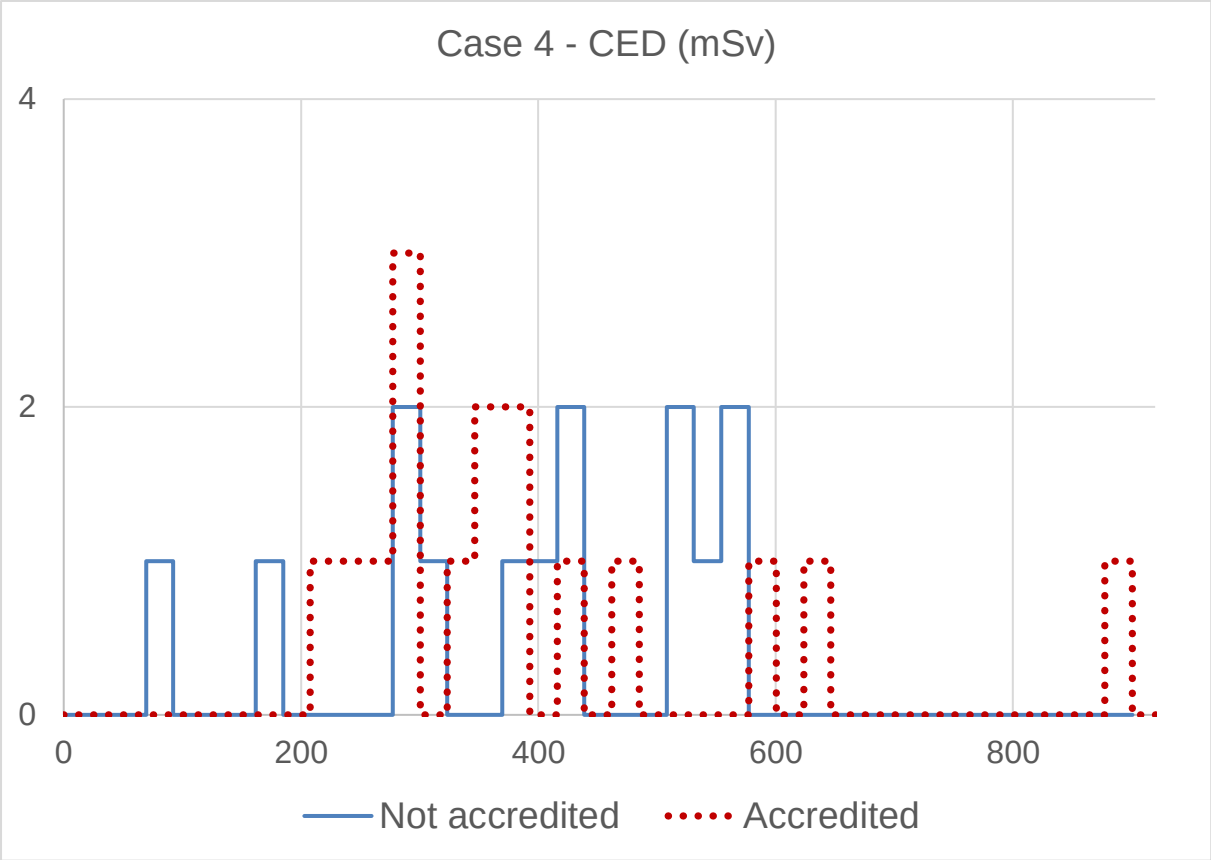


Figure 8-9: Comparison of the distribution of the results for committed effective dose (mSv) between participants with accreditation (dotted red line) and without accreditation (solid azure line).

8.4.8 *Step at which the analysis was terminated*

Table 8-21 provides a summary of the final step, as defined in RP188 and IDEAS, at which the submitted solutions terminated. In Case 4 the dose evaluation procedure starts according to the RP188 but since the committed effective dose exceeds the limit, and because DTPA therapy has been applied, the dose assessment procedure has to be continued, after few steps, with the structured steps prescribed by the IDEAS Guidelines.

Table 8-21: Terminating steps in RP188 and in IDEAS Guidelines.

Terminating Step	Number of submissions
RP188: Section E2 (Routine) Step 6	1
RP188: Section E2 (Routine) Step 8	2
RP188: Section E3 (Special) Step 1	8
RP188: Section E3 (Special) Step 6	19
Not specified	1
IDEAS: Stage 5A Step 5.6	1
IDEAS: Stage 5B Step 5.11	1
IDEAS: Stage 5B Step 5.11.4	1
IDEAS: Stage 5B Step 5.12.4	1
IDEAS: Stage 5B Step 5.13	2
IDEAS: Stage 5B Step 5.14	1
IDEAS: Stage 5C Step 5.15.1	8
IDEAS: Stage 5C Step 5.16.1	5
IDEAS: Stage 5C Step 5.18.1	1
IDEAS: Stage 5C Step 5.20.1	3
IDEAS: Stage 5C Step 5.21	5
Not specified	2

It is seen on the Table 8-21, that most of the participants defined Special Monitoring in the RP188 procedures, and terminated either at Step 1 or at Step 6. As for the IDEAS procedure the majority of the participants declared that they terminated the process at Stage 5C, Step 5.15 or 5.16. Another few participants went further on and submitted Step 5.20 and 5.21 as final step. One participant did not find the final step among the choice provided in the submission form and sent the result of Stage 5A Step 5.6 as a comment. This latter result cannot be interpreted because if the dose evaluation process terminated at this step it means that the assessed dose is below 1 mSv, which is obviously wrong since the submitted dose value was very much higher.

8.4.9 *Use of Software*

The dose assessment process in Case 4 is quite complicated, therefore, in order to meet the requirements, the use of a computer software tool is inevitably necessary. Several very sophisticated software have been developed that can be used for this purpose. A question was put in the submission form about the use and the kind of the code applied. In the following table the name and the version (if given) of the software are summarized.

Table 8-22: The names of the software and number of participants used for dose assessment.

Used Software	Number of submissions
IMBA (from ver. 4.0.13 to 5)	23
AIDE , 6	2
MONDAL3	1
Excel, Dosage (by BfS)	1
DCAL, V9.02	1
CALIN, V2 01	1
None	2

As seen in the Table 8-22, the great majority of participants used different versions of the IMBA code. Two participants indicated that they did not apply any software.

8.5 Errors performed by participants during the assessment

In this section two types of errors performed by the participants are discussed namely the Reporting errors and Method errors.

8.5.1 *Reporting errors*

One of the errors of this kind is based on a misunderstanding, namely: what does the term "best estimate" actually mean. The intention of the intercomparison was to indicate whether the assessment considered as the "best estimate" is that based on the lung data alone, on the urine data alone, or using both data sets simultaneously. However, nine participants interpreted the submission form as if they had to provide the best results of all attempts to find the best fit, separately based on lung, urine or both data. Consequently they provided in all three tables the answer of "Yes". This problem was clarified by subsequent correspondence.

Another typical error was when the participant did not give any answer. This kind of error has been experienced in many answers related to the data tables, absorption parameters, scattering factors, accreditations and terminating steps.

In one case the results was given in Sv instead of in mSv and one participant submitted exactly one order of magnitude higher value for f_1 value which is probably a typing error.

8.5.2 *Method errors*

Case 4 was a quite complicated case, which means in this respect that more assumptions can be appropriate and still remain within the frame of requirements laid down, either in the RP188 document or in the IDEAS Guidelines. Since the assessment requires a high reliance on the judgement of the assessors it was difficult to determine the concept behind the decision simply from the answers reported on the form; and therefore it is difficult to judge whether it is wrong or just another way of thinking. Therefore, this section will only mention the errors that seem to be obvious, and clearly differ from the approaches required by RP188 and IDEAS.

As for the data used for further assessment there were a great variety of submissions in selection of the number of data. In the case of the lung data, the range of the number of data selected extends from 2 to 21. It is hard to understand the selection of only a few data, especially the extreme number of 2. Apart from the first two measurements, which might not be relevant data due to the possible skin contamination, all data comply with the requirements given in the guidelines: i.e. they could not be considered as rogue data. There is no other reason to neglect monitoring data. In general, a better fit and lower uncertainty are expected by the use of a greater number of relevant data.

Subjective judgement plays a more important role in the selection of urine data for the evaluation process. Although there are 36 measured values available, the numbers of relevant data that can be used for dose assessment, according to the RP188 and IDEAS criteria, are much lower. The method based on the use of an enhancement factor is not applicable since the timing of urine sampling in relation to the DTPA administration does not meet the requirements according to the RP188 and IDEAS criteria; only one data might be considered as to whether or not it might be able to be applied within these requirements. Participants applying this method do not follow the referred documents. The majority of the participants selected urine data that was assumed to be undisturbed due to DTPA treatment. This depended very much on the judgement of the participants. The RP188-recommended value for plutonium is for 20 days delay after the last DTPA administration. The measured data indicated that this period should be increased. One participant even assumed 60 days, and found altogether 11 undisturbed data. Referring to the Table 8-12, 12 participants selected even more data, up to 22: which is possibly not correct according to the requirement. Two participants recorded activity data that was different to the measurement data that was actually provided.

Four participants provided unrealistically high Type B Scattering Factors for lung data: e.g. 2, 2.06 and 3. A value of 2.06 especially cannot be explained, and the use of the value of 3 is inexplicably high. These values surely do not comply with the RP188 recommendations.

Two of the participants defined lung absorption parameters very different to those recommended by any ICRP document, however the fits were excellent to the measured values ($p > 0.9$); and the calculated intake and committed effective dose values are also very close to the best Recommended solution. This gives the impression that the parameters have been derived by mathematical fit only, without referring to any biokinetic model to describe the real processes.

In connection with the terminating step, one participant did not find the final step among the choice provided in the submission form, and defined the last step in the IDEAS procedure Stage 5A Step 5.6 as a comment. This should be obviously wrong, since if the evaluation terminates at this step it means that the estimated dose is below 1 mSv, which is not compatible with the case description and data.

According to the definition the apparent intake should be less than the real intake. The participants' results predominantly indicated either equal values, or they just added 2 kBq to the calculated apparent intake in order to provide an estimate for the real intake (2 kBq being the total eliminated activity, as given in the case description). However, six participants provided higher values for Apparent Intake than for the Real Intakes: these results can be obtained in the fitting process on different data sets, especially if the associated uncertainties are high; however, it is principally not correct.

9. General considerations of the intercomparison action

9.1 Summary statistics of the cases

The overall results of the intercomparison action are reported in Table 9-1.

Table 9-1: Statistical analysis of E(50) – excluding outliers

Case number	1	2	3	4
Number of submissions	58[(a)]	56	38	31
Number of outliers	7	12	8	1
Parameters without outliers				
Geometric Mean (mSv)	0.925	6.44	6.36	381.6
Geometric Std. Dev. (mSv)	1.07	1.035	1.62	1.43
Robust mean	0.910	6.56	5.6	388.1
Robust standard deviation	0.077	0.41	4.4	145.5
Relative RSD (%)	8.5	6.3	79.0	37.5
Ratio max/min	5.1	3.15	4487	10.9
Note	*Estimation using data from OIR Part 2*	*Results refer to total committed effective dose for all intakes*	*GM and GSD exclude result reported as zero*	*Reported 'best estimate'*

[(a)] 61 participants sent results for Case 1, but only 58 results with application of the OIR models were received. This table refers to the corrected data in Table 5-9.

9.2 Comparison with previous ICEs

Several intercomparison exercises (ICEs) similar to the current exercise have been organised over the last few decades. In those exercises the spread of the submitted results was presented in terms of geometric standard deviation (GSD) values and numbers of evaluated outliers. These indicators have also been calculated for the present exercise, using the same procedure for identification of outliers as for all the previous inter-comparison exercises. In this way a comparison of the current results with those of previous ICEs is possible. This comparison is shown in Table 9-2, Table 9-3 and Table 9-4..

Table 9-2 compares relatively straightforward cases of special monitoring. It is possible to see a decrease of the value of GSD over the time-course of the ICEs. The greater complexity of the case from IDEAS/IAEA ICE can justify the difference in between 1.40 and 1.07 in GSD. It is considered that the slightly higher percentage of outliers for the ICIDOSE case is due to the very narrow distribution of the results, as indicated by the GSD value.

Table 9-2 : Statistical analysis of E(50) – comparison of previous inter-comparison exercises with ICIDOSE Case 1

Inter-comparison	Radionuclide	N submitted	N outliers	GSD
3rd European (Case 2) #	^{90}Sr	38	4 (11%)	1.78
IDEAS/IAEA (Case 3) §	^{60}Co	62	6 (10%)	1.40
ICIDOSE 2017	^{60}Co	58[(a)]	7 (12%)	1.07

[(a)] 61 participants sent results for Case 1, but only 58 results with application of the OIR models were received.

= reference (Doerfel 2000)

§ = reference (IAEA 2007)

Iodine cases of a similar grade of difficulty were presented in the three ICEs, from 2000 to date. It can be seen on Table 9-3 that there is an improvement between 3rd European ICE and IDEAS/IAEA ICE; the values for the IDEAS/IAEA and ICIDOSE cases are practically the same, with a slight improvement in overall performance for the ICIDOSE case.

Table 9-3: Statistical analysis of E(50) – comparison of previous inter-comparison exercises with ICIDOSE Case 2

Inter-comparison	Radionuclide	N submitted	N outliers	GSD
3rd European (Case 3)	^{125}I	38	2 (5%)	1.50
IDEAS/IAEA (Case 4)	^{131}I	63	13 (21%)	1.07
ICIDOSE 2017	^{125}I	56	12 (21%)	1.04

Complex cases, as those involving transuranic elements, were used to compare the results of Case 4. Results are reported in Table 9-4. The evaluations related to the 3rd European and IDEAS/IAEA exercises do not consider any decorporation therapy. For the 3rd European (Case 6 Subject A) the assessment of ^{239}Pu dose has been based on urine and faeces data , while for IDEAS/IAEA (Case 6 Part 1) the ^{241}Am assessment has been based on combined chest, liver, skeleton direct measurements and urine and faecal excretion data.

As can be seen from Table 9-4 the number of submitted evaluations is similar in each intercomparison exercise, but it is possible to highlight an improvement of the overall results due to the reduction of the spread. The value of 1.43 for the GSD is indeed consistently lower than the values obtained in the previous intercomparison exercises, although the case was actually more complex due to the multiple DTPA administrations.

Table 9-4: Statistical analysis of E(50) – comparison of previous intercomparison exercises with ICIDOSE Case 4

Inter-comparison	Radionuclide	N submitted	N outliers	GSD
3rd European (Case 6 Subject A)	^{239}Pu	33	3 (9%)	2.40
IDEAS/IAEA (Case 6, Part 1)	^{241}Am	35	3 (9%)	2.10
ICIDOSE 2017	^{241}Am	31	1 (3%)	1.43

9.3 Conclusions

The IDEAS/IAEA ICE was conducted with the aim of testing the then recently approved IDEAS Guidelines, proving that this document contributed to the harmonization of the results. The availability of RP188 and its comprehensive set of recommendation has now confirmed and strengthened this trend.

10. Discussion at the workshop

A participants' workshop was held at the premises of BfS, Oberschleißheim, Germany on 18th to 19th October 2018 and was attended by 40 persons, representing 35 participating institutions; among the 40 workshop participants, two joined the meeting via web-broadcast. George Etherington, coordinator of the Working Group that drafted RP188, also participated in the workshop and provided his comments as an external reviewer. This chapter focusses on the key points that were raised for discussion at the workshop. The first four sub-sections record the key technical points relevant for each case; in each case the comments proffered by the external reviewer are provided separately from those raised by people directly involved in the intercomparison (either as participants or as members of the Core Group). It should be noted that the intention in this chapter is to simply record the key points raised for future reference, and not to engage into further detailed discussions, recommendations or guidance within the scope of the report.

The last two subsections provide a more general summary of the comments relevant to the practical application of RP188; and then a review of the 'lessons learned' from the conduct of the intercomparison exercise, which might be of practical help for planning future intercomparison exercises. The comments in the sub-section on 'lessons learned' are segregated by Core Group, participants and external reviewer because it is recognised that each of these groups might have different perspectives.

10.1 Case 1: simple special monitoring, ^{60}Co

10.1.1 *Comments from participants and Core Group*

Using measurement data sequentially:

The case description provided a number of measurement data but requested that the assessment be progressed sequentially, only using the data that is relevant for a sequential assessment. RP188 actually requires to make a preliminary check only on the first available measurement, and then look for additional data if required by the severity of the case. Since in the case description all data were provided simultaneously, there was discussion on whether all the data should be used, because in a real case an assessor would likely use all the data that is available.

This is primarily an issue for how to conduct an intercomparison which is not being progressed in real time. However, there may be real-case issues when plans for future measurements and sampling have already been instigated. Should an assessor wait until all anticipated data is reported, or terminate an assessment if so indicated by data that is already available?

Assignment of Scattering Factors:

How reliable is it to assign 'default' scattering factors to reportedly 'True 24-hour' urine samples, or to urine samples collected within a day following an exposure?

Should an assessor exercise some discretion to assign higher scattering factors in these cases?

…If so, then how is this justified/qualified?

Transcribing reported units:

Some issues were raised concerning the urine data, since the case description was not very clear about the units used and if and how the first sample (spot sample) had been normalized to a 24-h sample.

Treatment of rogue data:

The Reference Solution (using OIR models) indicated that the last urine datum should be considered as 'rogue data' and not included in the assessment. Another suggestion was to increase the Scattering Factor for suspected data in order to improve the fitting without excluding data: how is this justified/qualified?

Prioritising WBM over urine data:

The case description provided a first WBM measurement and a first urine measurement on the same day. The data were specifically chosen with the primary aim to enhance the differences between old and new reference data, so the choice of the type and quality of provided data resulted in this being partially inconsistent with "real-life" experience; some participants questioned which of the provided data actually should have been used for the assessment. Based on that, some discussion arose about the extent to which the assessment can be affected by which of these measurements the assessor presumes to use as the first datum for a sequential assessment. Further guidance on how to prioritise the results from different measurement techniques might be helpful in such circumstances.

10.1.2 *Comments from External Reviewer*

Case Description:

Case Descriptions need to be more precise about whether the full dataset provided should be taken into account; i.e.:

- Does the data represent the results that would be obtained (in the future) if the decision is made to request measurements or samples, and the measurements are subsequently made at the times indicated (or samples are provided at the times indicated) ?
- Or are they the results of measurements that should be assumed to have already been made?

This is important if we wish to test decision-making on the need for further monitoring measurements.

Test for goodness of fit:

RP188 states that the calculation of chi-squared and test of goodness of fit should be performed, but ISO 27048 doesn't include this step. Chapter E of RP188 could be revised to resolve this inconsistency. (Note that this observation has also been made within the Reference Solution and the associated presentation to the workshop.)

10.2 Case 2: simple routine monitoring, ^{125}I

10.2.1 *Comments from participants and Core Group*

Vapour or aerosol assumptions:

There was not a significant difference between the committed effective doses reported by participants who had assumed exposures to aerosol compared to those who had assumed exposures to vapour; however, there were significant differences in the estimated values for intake. This might be an issue if there is a requirement to report intake as well as dose, e.g. for regulatory or operational purposes.

Change between routine and special monitoring:

It is noted that most participants correctly transitioned between routine and special assessments.

Setting the date for an unknown intake event:

The Reference Solution assumes that unknown intakes occurred at mid-points during a monitoring period: it was noted that for the special assessment relevant to the second exposure period, an assumption of an intake time other than the mid-point did not result in any significant improvement to the fitting.

Routine monitoring period:

The date of the fourth monitoring was strictly outside the tolerance range as specified in ISO 20553: (ISO 2006) is it still valid to refer to this measurement as part of a routine assessment? Or is the ISO 20553 requirement primarily intended for the planning of routine monitoring programmes, and therefore not a strict requirement for assessment processes? And so does the assessor have discretion to respond to the measurement data as it is reported, even if at variance with ISO 20553? (This was the judgement applied in the Reference Solution.)

10.2.2 *Comments from External Reviewer*

Test for contributions from past intakes:

With regards to the test to determine whether the measured value should be attributed to an earlier intake in routine monitoring: some participants appeared not to understand how to apply this test. RP188 should include the relevant paragraph from ISO 27048, rather than just referencing that paragraph.

10.3 Case 3: complex confirmatory and special monitoring, $^{234,235,238}U$

10.3.1 *Comments from participants and Core Group*

Dietary factors:

A number of comments indicated that the preferred 'instinctive' assessment would have been for some form of dietary/environmental exposure, but that there was insufficient information in the case description to justify recording this as the formal assessment.

The use of non-significant air activity measurements:

The case description indicated that the worker and workplace would have been subject to comprehensive air activity measurements, but that no evidence of air activity was reported from these measurements. Uranium has a low specific activity, such that a release giving rise to a significant inhalation dose would be expected to generate a significant dispersion of airborne material. Can this lack of evidence of air activity be used to justify an assumption of exposure by ingestion instead of inhalation? It is noted that these two assumptions lead to significantly different estimates of committed effective dose.

Contributions from environmental exposures:

Some participants had subtracted an allowance for contributions from environmental exposures from the urine measurement data, variously by reference to IDEAS Guidelines, national defaults, experience etc. It was suggested that more specific guidance might be beneficial.

There was a point of view expressed that the use of a general 'natural background' value is wrong, because there is a wide range of values for different people: measurements that were done on uranium 'natural background' in non-occupied men and women revealed values between 4 to 60 ng/l. Similarly, it was commented that while a pre-work blank measurement may represent the "natural background" of a worker at, for example, the age of 20-25, this value may change substantially at older ages, or as a result of some chronic diseases due to changes in the metabolism processes. Therefore the usefulness of assumed values for 'natural background' or of obtaining pre-work blank samples might be of limited use and should be questioned.

It was suggested that the same test as is applied to detect new intakes from contributions from previous occupational intakes could also be applied to determine if a uranium-in-urine measurement was significantly different from the expectation due to environmental exposures: i.e. by application of ISO27048 equation [4].

It was reported that, in a separate but related study, it was observed that particular dietary habits might have enhanced the absorption (and hence the uptake) of uranium from dietary exposures, without an actual increase in the content of uranium (i.e. intake) in the diet. If these observations are confirmed by further studies, then the whole concept of looking for an individual-specific natural background would be questionable.

Setting the date for an unknown intake event:

The Reference Solution for this case applied a literal application of IDEAS Guidelines paragraph 5.12 and chose a notional intake date (on day 1) which optimised the statistical fitting. In this case the statistical improvement to the fitting was considered to be sufficiently meaningful to justify a deviation from the default, mid-point assumption. As a general question: should a quantitative criterion be indicated to justify deviations from the mid-point assumption?

10.3.2 *Comments from External Reviewer*

Reference Solution:

The decision that intake must be assumed to be pure inhalation is questionable. In this Case the absence of PAS or SAS results (particularly for uranium) represents good evidence that the intake should be assumed to be at least partly ingestion.

RP188 could give more advice on the interpretation of air sampling data in such circumstances.

Further sensitivity analyses:

For Cases with assessed doses in excess of ~6 mSv, RP188 could recommend the use of additional sensitivity analyses and give recommendations for further investigations.

Subtraction of natural background levels of uranium in urine:

For the treatment of subtraction of natural background levels, RP188 could now refer in more detail to ISO 16638-1 (ISO 2015b) (not published when the Technical Recommendations were completed). When the effect on assessed dose is significant, ISO 16638-1 specifies:

- Isotopic measurements (for DU and enriched U exposures)
- Measurement of natural background levels in urine for the worker before start of work, OR
- Measurements on a representative population of unexposed workers, OR
- Measurements on representative samples of drinking water, OR
- Use of published data, but…
- it must be demonstrated that the background value used is representative of the worker.

10.4 Case 4: very complex special monitoring, ^{241}Am

10.4.1 Comments from participants and Core Group

Reported lung measurement data:

Should the lung measurement results be used directly as reported in the case description, or should they be used with caution, with the consideration that the results might be potentially affected by contributions from activity in other organs? Does this affect which of the lung measurement data should be selected/rejected for the assessment? In addition it was suggested that the first two reported lung measurement data, which were potentially affected by external contamination, might be included in the assessment process by assigning larger values for the relevant Scattering Factors.

Ingestion:

All submissions for this case indicated that inhalation was the sole exposure pathway; however, in such an instance of a very large exposure, should a contribution from an ingestion pathway be considered as well as the (untested) assumption of 100% inhalation? However, it is noted that according to the IDEAS structured approach, even if a contribution from an ingestion pathway is assumed, the procedure stops when an acceptable fit has been achieved by fitting the inhalation parameters only. So for this case there would be no changes in the procedure and results due to the assumption of contributions from ingestion.

Simultaneous fitting of the whole data sets:

Should the model fitting procedures be applied simultaneously to the whole data set covering the entire monitoring period, or should the data sets before, during and after DTPA treatments be considered as discrete data sets, with discrete (non-simultaneous) modelling procedures? The former approach presumes that measurement data – especially urine measurements – can be treated as a coherent population, and that the impact of DTPA treatment is incorporated into the modelling by various combinations: excluding affected data, applying enhancement factors, adjusting model parameters. The latter approach, if applied in this case, would result in the major component of the effective dose being assessed from only very limited data, collected nearly two years after the exposure, and so would give rise to a very un-reliable assessment.

Scattering Factors for DTPA-affected data:

The typical approach to accommodate DTPA-affected data into an assessment is either to attempt to derive an 'enhancement factor' or simply to exclude the affected data from the assessment process (this latter approach was advised in the Recommended Solution). An alternative suggestion is to apply case-specific SF values (by judgement) to data which is suspected of being affected by DTPA treatment. How would such SF values be justified/qualified? Would this be any more or less reliable than deriving 'enhancement factors'? Would this approach be appropriate to attempt to derive a fit to DTPA affected urine data? The effect of DTPA is systematic (it goes in one direction, i.e. to enhance the excretion) and this cannot be taken into account simply by increasing the SF values on the affected samples. The same question has been discussed in connection with the first two lung data, where these data could potentially be affected by some skin contamination in a systematic way (i.e., to provide an overestimation of the lung activity). There were participants who considered this effect by increasing the SF values just for these two data, as compared to the Recommended Solution where these two data were omitted from the fitting process.

Simultaneous fitting of lung and urine data for DTPA cases:

It is generally presumed that DTPA treatment primarily acts on activity which has been incorporated systemically, but not on activity in the respiratory tract; therefore, is it meaningful to attempt simultaneous modelling of lung monitoring data and urine measurement data (i.e. as an indicator of systemic activity)? It was also questioned whether it is meaningful to modify HRTM parameters to attempt to model systemic (urine) measurements which will/might have been affected by DTPA treatment, when it is presumed that lung activity won't have been affected by such treatment.

The use of DTPA enhancement factors:

There were various approaches and comments regarding the use of DTPA 'enhancement factors' to be applied to urine measurement data which is presumed to be affected by DTPA treatment. The Recommended Solution considered that such enhancement factors could not be used in this case, because the case data did not satisfy the requirements for their use; other approaches applied default values (as advised by local requirements, procedures and experience), or attempted case-specific determinations of 'enhancement factors' from the data reported in the case description.

Identifying data which has been affected by DTPA:

The main issues for discussion were whether the default recommendation should be applied (exclude urine data within 20 days of DTPA treatment), or should the instruction in the case description be adhered to (a 30-day exclusion period), or should an assessor exercise discretion to determine case-specific 'exclusion periods' based on their own judgement/experience.

Varying model parameters:

There was a wide range of different approaches to which model parameters were (or should be) varied in order to obtain a reliable assessment. Existing guidance is available (IDEAS); however, there might be scope for further discussions and guidance on this topic: e.g. the order by which parameters are varied, the required justifications for varying a parameter, constraints on the range by which the value of a parameter can be varied etc.

Terminology:

There was some confusion regarding the meaning of the terms "apparent intake", "real intake", "best estimate" etc. This relates to the text in the case description data and also the RP188 and IDEAS Guidelines that requires clarification/correction in these documents.

10.4.2 *Comments from External Reviewer*

Recommended solution:

The "Recommended Solution" should explain in more detail the method that was used to reject urine data that are considered to be influenced by DTPA treatment.

Rejection of data affected by DTPA:

RP188 could provide advice on how to determine individual-specific criteria to reject such data (e.g. delay times other than up to 20 days after DTPA treatment). RP188 could also:

- recommend the collection of urine samples after the end of DTPA treatment;
- and collection of urine samples at times that would allow the "enhancement factor" approach to be used.

RP188 should be clearer on the point that monitoring data must not be excluded except where strictly defined criteria apply.

Lung measurement data:

RP188 should address the issue of interference of lung measurements by activity in other organs.

Terminology:

A better explanation of the concept of "apparent intake" is needed.

10.5 Comments on Application of RP188

This section provides a brief overview of the key issues that were discussed about the practical use of the RP188 document during this intercomparison exercise. It is important to note that the RP188 document is a very recent publication, such that few of the participants will have had any previous experience with the application of this document. On the other hand, the assessment processes which it defines are generally available and published in related documents.

10.5.1 *Comments from participants and Core Group*

Relation between RP188 and related documents (Standards, Guidelines):

It is noted that the original intention of the authors of the RP188 was to avoid to replicate existing information, as far as is reasonable. This necessitates that many related and referenced documents (e.g. ISO20553, ISO27048, IDEAS Guidelines) are available to the assessor, and might need to be consulted in addition to the RP188. It was considered that the use of the RP188 (for this exercise) might have been made easier if it contained more specific information directly replicated from reference documents: e.g.

- the routine monitoring period tables and tolerances from ISO20553 (tables 3 to 6);
- the equation for checking if a result is significant when compared to contributions from past intakes; from ISO27048, equation [4];
- more specific reference to ISO16638-1 (for uranium exposures);

It was also noted that some confusion was encountered due to the need to engage in cross-referencing between RP188 and related documents during the course of an assessment process.

Terminology:

Some of the terminology within the tables and flow charts can appear difficult to understand from a literal reading, although the intending meaning behind the terminology is usually obvious: e.g.

- "Check if unexpected exposures can be excluded…" (Table E.1)
- "Check if an intake via wound … can be ruled out" (Table E.2)

It is noted that both these phrases are extracted verbatim from the reference document; and also that the meaning becomes clear if the related text is read, and not just the text in the tables.

Use of Tables and Flow Charts:

It is noted that is important that the full text is read and applied in order to conduct an assessment according to RP188, and that an assessor should not simply rely on the text contained within the tables and flow-charts: these are included as an aid and guidance, and not as a surrogate for the full text.

DTPA specific recommendations:

It was discussed that during any real case requiring DTPA treatment there are likely to be case management issues which would benefit from a close collaboration with the dose assessment process, and for which the assessor should need to consider: e.g.

- Communications between medical and dosimetry personnel;
- Coordinating urine sampling times with DTPA therapy schedules to help assure that the urine sample data is as useful and usable as possible – both for dose assessment and determining the effectiveness of the treatment;
- Communications to patient;
- The need to continue urine sampling well after DTPA-affected period to help determine a reliable assessment.

Determination of Effective AMAD:

In case of inhalation more attention should be paid to collect early faecal samples together with lung activity measurement in order to get more information on the probable AMAD value by calculating the Effective AMAD.

Case studies and examples:

RP188 contains six example case-studies, which have been rated very useful by the participants. These examples, however, only cover a small subset of the aspects potentially encountered during the evaluation of occupational incorporations; it was suggested that a greater scope and number of such example case studies would be beneficial to harmonize the application of RP188.

Harmonization v. expert judgement:

There was some concern that too much focus on using RP188 as a means to engender 'harmonisation' could inadvertently have a negative consequence for exercising and developing expertise by practitioners. This is something for which there needs to be a balanced approach. However, even if RP188 specifies a very well-defined methodology and rationalises the sequence of the steps to be performed, there are many stages at which assessors must use their own judgement to interpret the case, assess the obtained results and take decisions.

It was suggested that RP188 should be seen as a tool for use by the assessor but not as a prescriptive methodology: if an assessment was conducted according to RP188 then it would be valid to cite RP188 as the quality assurance for the assessment; if an assessment deviated from the processes defined in RP188 then the assessor would need to justify the case-specific reasons for doing so, and would also need to provide additional quality assurance (e.g. by peer review).

It was also noted that RP188 is an excellent tool for newcomers in the field of internal dosimetry, because it guides them step-by-step all through the dose assessment procedure, and gives valuable theoretical background on each of the actions to be performed.

The use of Scattering Factors to represent uncertainty

In all four cases, and also in general, there is some inconsistency between the way in which uncertainties are specified in RP188 (and also IDEAS) and by measurement laboratories. In these documents uncertainties are specified by Scattering Factors, which are actually the geometric standard deviation of the assumed distribution, which means that a log-normal distribution is assumed. In all four cases measurement uncertainties were given as the standard deviations of an assumed normal distribution (±). Therefore, these uncertainties had to be 'translated' from normal distributions to log-normal distributions, which is not absolutely correct. It is suggested that it would be beneficial to have greater explanation and clarification regarding the consistent use and translation between the two uncertainty specifications.

10.5.2 *Comments from External Reviewer*

Relation between RP188 and related documents (Standards, Guidelines):

Simultaneous use of different documents (i.e. ISO 27048 & IDEAS Guidelines) can be difficult to follow.

RP188 should make clear that the user needs access to both ISO 27048 and the IDEAS Guidelines in order to implement the recommendations.

Possible revisions for clarification of RP188:

RP188 needs to be clearer on the purpose of each Step in the dose assessment process.

Precision of language should be considered, to ensure consistency of outcome for different users.

Reporting errors:

Reporting and transcription errors seem to be rather common. Some simple advice could be given on data handling procedures, methods for checking results and quality control.

Possible technical revisions/additions to RP188:

RP188 could give more advice on the interpretation of air sampling data.

For the treatment of subtraction of natural background levels, RP188 could now refer in more detail to ISO 16638-1 (not published when the original text of RP188 - then known as the Technical Recommendations - were completed).

10.6 Lessons learned on the management of the exercise

10.6.1 *Core Group*

The standardised PDF form templates, used for participants to submit their results, led to an effective means to collate and process data; however, it was noted that for more complex cases – especially for case 4 – a more general comments section would have been useful to properly understand the participant's methodology. It is recommended that for future intercomparisons further thought needs to be given to: the potential complexity of the cases; what information is required from participants to be able to record their methodology and not just their results; the administrative resources available to be able to collate and process the submitted data; the number of expected submissions.

This was the first international internal dosimetry intercomparison which utilised 'robust statistics' (ISO 13528) as part of the process for analysing the submitted data. This is considered to be an effective statistical tool and is less susceptible to the distorting effects of a small number of non-consistent data (i.e. rogue data or outliers). It turned out that the statistics provided by the Robust Statistics were qualitatively in agreement with those obtained using classical statistics methods used in the previous exercises. This technique is recommended for future intercomparisons.

Further consideration could be given to if and how such intercomparisons might be used in the future for more formal or statutory 'performance test' or 'accreditation test' purposes. This will need to consider how reliable and authoritative the 'reference solutions' are, and the use of a defined 'acceptable range'.

10.6.2 *Participants*

The period of about 10 months between the deadline for submission of the results and the workshop was considered to be too long for an effective participation to the discussions, as it might be not straightforward after such a long time to have a proper recollection of the justification of the choices made. It was suggested that this period should be significantly reduced in future intercomparisons.

Additional comment fields on the PDF forms would have helped to explain the methods and reasons behind the reported results.

Some aspects of the design of the PDF form were not obvious: e.g. the use of the "➔" sign directing participants to fill in a second drop-down list when the assessment progressed to steps from the IDEAS Guidelines.

On the PDF form some list items were missing from the drop-down lists for IDEAS Guidelines: e.g. the list only went as far as stage 5C (for case 3 some participants progressed as far as IDEAS stages 6, 7 or 8).

There is a general interest in internal dosimetry intercomparisons being conducted on a more frequent and regular basis.

10.6.3 *External reviewer*

As part of the process for submitting solutions participants should be asked to indicate the extent to which they have followed RP188.

Additional information was sometimes needed in order to test the applicability of the Technical Recommendations. For example:

- information on natural background levels of uranium-in-urine (Case 3);
- quantitative criteria to allow a judgement to be made about whether "unexpected exposures can be excluded" (All Cases). ISO 27048 recommends that "adequate quantitative criteria be set up in advance".

The Core Group considered that the 'acceptable range' of assessed intakes and doses was, for all cases, **Ref / 3** to **Ref * 3**. Perhaps the range should reflect the complexity of the case.

Case Descriptions need to be more precise about whether the full dataset provided should be taken into account. i.e.:

- Does the data represent the results that would be obtained (in the future) if the decision is made to request measurements or samples, and the measurements are subsequently made at the times indicated (or samples are provided at the times indicated) ?
- Or are they the results of measurements that should be assumed to have already been made?

This is important if we wish to test decision-making on the need for further monitoring measurements.

Closer examination of individual assessments is needed to understand differences, particularly with reference to the recorded "terminating step" for the submitted assessments.

11. Conclusion and perspectives

The overall conclusions are that this was a successful intercomparison in terms of the extent of interest and participation: submissions were received from 66 separate participants, and 40 participants attended the workshop. All participants applied RP188 for their assessments, to a greater or lesser extent. This intercomparison exercise was a very effective method to promulgate the use of RP188, and to encourage familiarity with its use. In addition the workshop was an effective forum for sharing experience and interpretations; and also useful for obtaining constructive feedback, which will:

- aid the general sharing and development of technical expertise;
- help to develop a harmonized interpretation and application of RP188;
- inform future revisions to RP188;
- inform the design and conduct of future intercomparisons.

The intercomparison was initiated to achieve a number of set objectives, as below:

The primary objective was to assess how effective the RP188 document is when applied in practice. It is observed from the reported estimates of intake and committed effective dose that the application of RP188 led to closely convergent values for the more straightforward cases (case 1 and 2); and that the spread of results for these cases compares favourably to similar cases from past intercomparisons. It is therefore concluded that for such cases – i.e. those which do not necessarily require input from expert assistance - the RP188 can be applied effectively in practice.

There was a greater degree of divergence for the more complex cases (Case 3 and 4), both in terms of the reported values for intake and committed effective dose, and also in the underlying judgements and assumptions. It is noted that both cases required the assessor to exercise a certain degree of subjectivity – sometimes beyond the scope of RP188 - in how to interpret the data reported in the case descriptions. It is also noted that RP188 recommends that more complex and significant cases should be referred for expert assistance. Therefore, it is concluded that for these more complex cases the practical application of RP188 is reasonably effective, but primarily as an indicator for when to refer to expert assistance; indeed, the application of RP188 alone and without expert assistance would not be advisable for such cases.

A number of technical and procedural aspects have been raised from these cases during the intercomparison, and particularly the workshop, which will help further develop methods and practices. These are summarised in the conclusions for the secondary objectives below.

11.1 Case 1: secondary objectives

Comparison of ICRP Publications 78/119 or and ICRP OIR Publication Series

A secondary aim of this exercise was to make participants aware of the new ICRP reference data and the possible impacts these new data might have on the dose assessment, both in terms of procedures to be used and final estimates. The submitted results indicate that the majority of participants properly applied the different reference data as required. The observed deviations from the reference solutions were not ascribable to an incorrect use of the different sets of reference data, rather to an incorrect application of the recommendations of RP188 and/or to ambiguities in the case presentation and in the formulation of the recommendations.

11.2 Case 2: secondary objectives

Determine the significance of each result in detecting new exposures

Although all the results of the evaluations carried out by the 56 participants remain within the acceptable interval of [Ref / 3; Ref * 3], the lack of information related to the final step reached meant that it was not possible to verify the effective application of RP188 document for 7 participants (12% of the submitted results).

The test proposed for the verification of a new intake for the third monitoring period, although not explicitly reported in the text of chapter E2 (it is only referenced), but present in Example 3 of Annex II, has been correctly applied only by 20 (i.e. about one third) of those who submitted results.

The correct application of RP188 in the first monitoring period is almost universal, being very direct (the correct final step has been reached in 60% of the cases) while for the second period only 20% of them reach the correct final step.

Further effort should be made to improve the general application of RP188 methodology.

Determine the residual contributions from earlier exposures within successive measurement data

In most cases of acute intake assessments (32 cases out of 47, i.e. two thirds) the calculation of the contribution of the previous intake on the subsequent measures was correctly performed, using the mid-point of the monitoring period as assumed intake date.

This does not alter the fact that there have been indications of intake dates at the beginning of the monitoring period, or even of missing information, that amounts to about a third of the results submitted for acute intake.

There are also many incorrect and unnecessary determinations of the contribution of the second intake on the special monitoring measures (third and fourth measurements) for a total of 80% of the 56 submitted evaluations.

Ultimately there is scope, through training, for the improvement of the application of RP188 and for the harmonization of the application of the methodologies proposed for routine monitoring, and also in relation to the transition from routine to special monitoring procedures.

11.3 Case 3: secondary objectives

Determine how to incorporate the data for the three uranium isotopes into the overall assessment

From the 38 submissions for this case there were nine different methods reported for treating the mix of three uranium radionuclides within the final assessment. This might be partly explained by various different methods being suggested or implied by ISO27048 and ISO16638-1, and also that some of the data was indicated to be 'below decision threshold'. The range of different methods used only has a trivial impact on the finally estimated values for total committed effective dose. However, it is concluded that the recommended processes for the treatment of radionuclide mixes should be reviewed, and greater clarification issued in future recommendations and guidance.

Compare initial estimates (from one measurement) to final estimates (from all measurements)

Nearly half of the participants made the assumption of acute inhalations for both the initial and final estimates; therefore this data was used to derive the comparison between initial and final estimates. The comparison indicated a reasonably good correlation in the ratio of final/initial

estimates, with an average of approximately 1.7. This is a significant ratio, although less than the factor of 3 which is generally considered as the maximum desirable underestimate. It is noted that this case incorporated a range of different sources of potentially significant uncertainties; therefore it is concluded that the inclusion of the latter data (special samples) to determine a more refined final estimate was beneficial and proportionate, if only to attempt to reduce the range and impact of the inherent uncertainties.

11.4 Case 4: secondary objectives

Determine which data should be used within the assessment, excluding those which might be affected by the DTPA treatment

In this case one of the most important issue was the selection of monitoring data for the dose assessment process from the complete data set given in the case description.

As for the lung activity data it was assumed that the DTPA treatment has no influence on the measured values, consequently all reliable data could be used for further evaluation. In this respect the first two measured data could be the subject of personal judgement due to the potential contribution of body surface contamination. About one third of the participants used all 21 provided data values, while another third disregarded the first two data and considered only 19 data values. The remaining one third chose different numbers of data, in the range of 2 to 16. It could be concluded that the lower the number of data used then the higher the probability of receiving biased results. It is advisable in such intercomparison exercises that participants are requested to explain in their answers the reason for omitting data provided in the case description. This is an even more critical issue for urine data due to the effect of DTPA administration. The basic question that came up was whether *"more than 20 days"*, as the waiting time given in the RP188 document, could be applied in this case. It turned out clearly from the measured data that a 20-day waiting time is not sufficient; this leads again to the question of personal judgement. Some participants used the recommended value, but assumptions were reported of up to 50 days. The conclusion can be drawn from this case that the waiting time after which the DTPA administration is no longer affecting the activity excreted by urine is case dependent, and this should be considered in further case studies and intercomparison exercises.

Another question is when and how to apply the "enhancement factor" in order to use those data for dose evaluation that are still affected by DTPA treatment. This can only be done in very well defined conditions for the timing between urine sampling and DTPA administration, but the case description provided only one measurement that could be interpreted as fulfilling the requirements. According to RP188 a value of 50 is recommended as an enhancement factor. It is obvious that this factor can vary case by case, therefore it can be concluded that this method should be avoided when there are sufficient number of data which have not been affected by DTPA.

Finally the question arises whether future intercomparison exercises should only provide those urine data that are definitely not affected by DTPA, or should this remain as a subject of free judgement by the participants, as it was in the present exercise.

Based on the experiences of this exercise, it is recommended that future intercomparisons provide the possibility for participants to make comments on their evaluations and assumptions, at least in very complicated cases.

Determine a 'real intake' – i.e. the actual initial intake; and an 'apparent intake'

The term "apparent intake" was wrongly interpreted by a number of participants. By definition, "… it corresponds to the real intake minus the activity removed from the body as a result of the therapy." Consequently the apparent intake could never be higher than the real intake, as has been reported in a few submitted results. The apparent intake is calculated from the baseline excretion; that is from measured activities of urine samples taken after the enhancing effect of DTPA administration. Since this depends on the assumed waiting time, as discussed above, the submitted values of apparent intake varied according to the participant's judgement. The confusion on the meaning of this term is readily seen from the submitted results. The problem also comes from the fact that only six early data were available for the real intake assessment, and only a few (a minimum of five) late data out of 30 were usable for determination of apparent intake. For this reason most participants considered all available data as a single dataset in the dose evaluation process. Only very few of them used the value of 2 kBq total eliminated activity due to the DTPA treatment, as given in the case description.

According to the experience gained in this exercise more attention should be payed to this issue by clarifying the terms and their use.

Another important outcome of this intercomparison was that the term "apparent intake" is not precisely defined in the RP188 document, since the eliminated activity should not be subtracted directly from the real intake; instead it is the *intake,* as calculated from the activity eliminated from the body as result of the DTPA therapy, that should be subtracted from the real intake.

11.5 Other observations

Use of robust statistics for collective analysis of submitted results

This was the first international internal dosimetry intercomparison which utilised 'robust statistics' (ISO13528) as part of the process for analysing the submitted data. This is considered to be an effective statistical tool and is less susceptible to the distorting effects of a small number of non-consistent data (i.e. rogue data or outliers). This technique is recommended for future intercomparisons.

Performance testing, reference values and acceptable range

This intercomparison was not intended for use as a formal performance test; however, the submitted results were analysed and presented in such a format that would enable a participant to refer to their own performance, if required for their own accreditation, approval, quality assurance requirements. This data included the report of 'reference solutions' and 'acceptable ranges' of a factor of 3 to multiply/divide the reference value, as well as the 'final step' of RP188 that an assessor should reach to indicate a successful application of RP188. It is recommended that future intercomparisons could consider if they are intended to be used as formal performance tests and, if so, will need to give careful consideration to:

- the nature and compexity of the selected case studies;
- the use of real or artificial cases and data sets;
- the additonal information provided with the data sets;
- the definition and provenance of reference values;
- the acceptable range for demonstrating satisfactory performance;
- the issue of certifications, and the scope of authority of such certifications;
- the procedures (if any) for failed tests and re-testing;
- the frequency of such tests;

- administration, logistics and costs issues.

Formal (existing) accreditation of participants

Participants were asked to indicate if they possessed any formal recognition (accreditation, approval, certification etc.). The intention was to determine if this might be a factor when analysing the results. However, it is concluded that for all cases (except Case 2, Total E(50) percentage RSD) there was no evident difference in the distributions of results between those participants which declared accreditation and those which did not.

Software

For all of the cases most of the participants declared that they applied some form of specialised software during their assessments. In most cases the distribution of the results for those participants who did not use specialised software show no evident difference from those that did use such software. One exception is for Case 1 and the assessment based on ICRP78 methodology. In this case the distribution of results for participants using software is significantly biased in relation to the ICIDOSE reference solution. It is considered that this finding is a consequence of there being no software currently available that follows the RP188 procedure, so the automatic routines of the program might have directed the solution towards a value different from the ICIDOSE reference. Additionally, the data for this artificial case were created using the new models from the OIR publication; therefore it understandable that the software, which are based on models and bioassay functions from the old publications, might encounter problems in analyzing the data. The other exception is Case 2, in which the distributions of results is narrower for values coming from participants who have used software tools.

Step of RP188 at which the analysis was terminated

In all cases it is noted that there is a wide range reported for the final step of the assessment process. This finding indicates that greater clarity and guidance on the application of RP188 as well as of IDEAS Guidelines would be beneficial. An additional issue might be with the definition of "terminating step": this was a terminology introduced for the purposes of conducting the intercomparison, but is not a concept which is explicitly defined in RP188.

Reporting Errors

It was noted that a number of participant submissions contained 'reporting errors': i.e. not considered to be errors with the approach, methodology or calculation, but errors incurred in the reporting of the assessment. Examples included:

- incorrect use of units (Sv instead of mSv);
- transcription errors;
- reporting parameter values which are not consistent with calculated values of intake or dose.

It is concluded that greater emphasis should be placed on the importance of quality control and diligence to assure the accuracy of information within formal reports and records.

Future intercomparison exercises

There is a general consensus that more regular and frequent intercomparison exercises would be desirable. (see also 11.6)

Future training activities

Future training activities may be envisaged to improve the application of the RP188 recommendations, taking advantage of the indications emerging from the present intercomparison; also with a view to developing a systematic course, repeatable over time, for the training of new staff in the field of internal dosimetry.

11.6 Outcome of a survey on participants' satisfaction

A web-based survey was conducted among the participants at the ICIDOSE 2017 intercomparison exercise from 7/12/2018 to 31/12/2018; twenty nine replies were submitted (44% of the total). Sixteen of the 29 respondents had also participated in the workshop (46% of the workshop participants). Focus of the survey was not only to assess the quality of the exercise and of the workshop, but also to investigate need and interest for intercomparison exercises on internal dosimetry on a regular basis.

Fifty-nine percent of the responses rated the ICIDOSE 2017 intercomparison exercise as excellent ("exceeded my expectations") and 34% as appropriate ("met my expectations") with only one response (3.5 %) rating the exercise as poor ("did not meet my expectations"). The average rating of the responses was 4.14 (on a scale of 5). The number of proposed cases and the time available for solving the cases were the two aspects with the lowest ratings (3.62 and 3.41, respectively). The exercise was considered very useful for increasing the professional experience (average rate 4.10).

The average rating of the workshop was 4.13; 60% of the responses of the workshop participants rated it as excellent ("exceeded my expectations"), and 40% as appropriate ("met my expectations"). The time available for presentations was the aspect with the lowest rating (3.13), utility of the meeting and quality and clarity of the organizers' presentation the best rated aspects (4.13).

All 29 responses confirmed the need of intercomparison exercises on a regular basis; three responses (10.3%) indicated that such exercise should be conducted yearly, 12 (41.4%) every second year, whereas 14 (48.3%) had no specific request on frequency. Nearly 80% of the respondents would be willing to pay a fee for participation to the exercise, suggested fees are around 300-500 € (in any case, definitely less than 1000 €). More than 50% would be willing to be part of the organisation of such exercises, with an additional 29% that might be interested to do so. Fourteen respondents (48.3%) say they have relevant monitoring data and/or case studies that could be used for a future exercise.

The most important factor affecting the decision to participate in a workshop is the relevance for the professional career (average rating 4.3); less important are travel and cost issues (3.4), other commitments (3.1) and workshop duration (2.8).

Fifty-eight percent of the responders share the opinion that the choice of the individual solutions to be shown at the workshop should be left to the organizers, and that enough time should be allowed for interactive discussions before disclosing the reference solution.

Summarizing, there is an evident need by the internal dosimetry community for intercomparison exercises at an international level. The organization of such exercises on a regular basis is a complex and time-consuming task, not easy to be achieved by resorting only to volunteers' contributions. The results of the survey seem at least to indicate that there is a rather broad basis of potential organizers of future intercomparisons. A possible alternative solution could be the set-up of a fixed structure dedicated to the regular conduct of this activity, e.g. in the form of a specific EURADOS Task Group or even of an association similar to what PROCORAD is in the field of radiotoxicology intercomparisons. The support of organizations like the European Commission, IAEA and other international bodies could be beneficial in curbing costs and fees and in facilitating the participation also for internal dosimetrists from less advantaged countries.

12. References

Castellani, C. M., J. W. Marsh, et al. (2013). "IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring Data". Braunschweig, EURADOS. **EURADOS Report 2013-01**

Doerfel H, A. Andrasi, Bailey, M.R. et al. (2000) "Third European Intercomparison Exercise on Internal Dose Assessment". **Report FZKA 6457** Forschungszentrum Karlsruhe (D)

Doerfel H., Andrasi A., Bailey, M.R. et al. (2006) "General guidelines for the estimation of committed effective dose from incorporation monitoring data". **Report FZKA 7243** , Forschungszentrum Karlsruhe (D).

EC (2014) Council Directive 2013/59/Euratom of 5 December 2013. Official Journal of the European Union, vol. 57, L13, 17 January 2014, . ISSN 1977-0677.

EC (2009) "Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation". **Radiation Protection RP160**, European Commission, Directorate-General for Energy and Transport, Directorate H – Nuclear Energy, Unit H.4 – Radiation Protection.

EC (2018) "Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides". **Radiation Protection RP188**, European Commission, Directorate-General for Energy, Directorate D – Nuclear Energy, Safety and ITER , Unit D.3 – Radiation Protection and Nuclear Safety.

IAEA (1999) "Intercomparison and biokinetic model validation of radionuclide intake assessment". IAEA, Vienna, IAEA, **Report IAEA-TECDOC-1071**

IAEA (2004). "Methods for Assessing Occupational Radiation Doses Due to Intakes of Radionuclides". IAEA. Vienna, IAEA. **Safety Reports Series No. 37**.

IAEA (2007) "Intercomparison exercise on internal dose assessment – Final report of a Joint IAEA-IDEAS project ". **Report IAEA-TECDOC-1568**

IAEA (2018) "Occupational Radiation Protection". IAEA. Vienna, IAEA. **General Safety Guide GSG-7.**

ICRP (1979). "Limits for Intakes of Radionuclides by Workers. ICRP Publication 30." Annals of the ICRP **2** (2-4).

ICRP (1988). "Individual monitoring for Intakes of Radionuclides by Workers: Design and Interpretation. ICRP Publication 54." Annals of the ICRP **19** (1-3).

ICRP (1991). "1990 Recommendations of the International Commission on Radiological Protection. ICRP Publication 60. ." Annals of the ICRP **21**(1-3).

ICRP (1994a). "Human respiratory tract model for radiological protection. ICRP Publication 66." Annals of the ICRP **24**(1-3).

ICRP (1994b). "Dose Coefficients for Intakes of Radionuclides by Workers. ICRP Publication 68." Annals of the ICRP **24**(4).

ICRP (1995). "Age-dependent doses to member of the public from intake of radionuclides: Part 3 Ingestion dose coefficients. ICRP Publication 69." Annals of the ICRP **25**(1).

ICRP (1997). "Individual monitoring for internal exposure of workers. ICRP Publication 78." Annals of the ICRP **27**(3/4).

ICRP (2006). "Human alimentary tract model for radiological protection. ICRP Publication 100." Annals of the ICRP **36**(1-2).

ICRP (2007). "The 2007 Recommendations of the International Commission on Radiological Protection. ICRP Publication 103." Annals of the ICRP **37**(2-4).

ICRP (2009). "Adult Reference Computational Phantoms. ICRP Publication 110." Annals of the ICRP **39**(2).

ICRP (2012). "Compendium of Dose Coefficients based on ICRP Publication 60. ICRP Publication 119." Annals of the ICRP **41**(S).

ICRP (2015). "Occupational Intakes of Radionuclides: Part 1. ICRP Publication 130". Annals of the ICRP **44**(2).

ICRP (2016a). "Occupational Intakes of Radionuclides: Part 2. ICRP Publication 134". Annals of the ICRP **45** (3/4).

ICRP (2016b). "Occupational Intakes of Radionuclides: Part 4. ICRP Draft for Consultation (14/7/2016)". To be published.

ICRP (2017). "Occupational Intakes of Radionuclides: Part 3. ICRP Publication 137". Annals of the ICRP **46** (3/4).

ICRP (2018). "OIR Data Viewer" Ver. 3. Electronic Annex accompanying the ICRP Occupational Intakeof radionuclides publication series.

Ishigure, N., M. Matsumoto, et al. (2004). "Development of software for internal dose calculation from bioassay measurements." Radiat Prot Dosimetry **109**(3): 235-242.

ISO (2006). Radiation protection – Monitoring of Workers occupationally exposed to a risk of internal contamination with radioactive material, ISO. **ISO 20553:2006**

ISO (2011). Radiation protection - Dose assessment for the monitoring of workers for internal radiation exposure. Geneva, ISO. **ISO 27048:2011**

ISO (2015a). Statistical methods for use in proficiency testing by interlaboratory comparison. Geneva, ISO. **ISO 13528:2015**.

ISO (2015b). Radiation Protection - Monitoring and internal dosimetry for specific materials - Part 1: Inhalation of uranium compounds. Geneva, ISO. **ISO 16638-1:2015**

Pázmándi, T., Andrási, A., Fehér, A. I., Kocsonya, A., Pántya, A., Szántó, P., Zagyvai, P. (2016). Calibration of a whole body counter for 241 Am with the LLNL chest Phantom. **Radiation Protection Dosimetry, Volume 170, Issue 1-4, 2016**, doi.org/610.1093/rpd/ncv400

Additional publications originated by ICIDOSE 2017

Castellani C. M., Andrasi A., Giussani A., T. Pazmandi and Roberts G.(2018): Preliminary Results of the ICIDOSE 2017 International Inter-Comparisoin on Internal Dose Assessment. Radiation Protection Dosimetry, doi: 10.1093/rpd/ncy160 (2018)

Giussani A., Castellani C. M., Roberts G. Andrasi A., and T. Pazmandi (2018):Preliminary outcomes of the ICIDOSE 2017 intercomparison action in relation to new ICRP models for occupational exposures HEIR 2018 - 12th International Conference on the Health Effects of Incorporated radionuclides , October 8th – 11th, 2018 , Fontenay-aux-Roses (F)

Pázmándi T., Castellani C. M., Andrási A., Giussani A., Roberts G.:(2018a) Intercomparison on Internal Dose Assessment (ICIDOSE 2017): preliminary results, 5th European IRPA Conference, The Hague, The Netherlands, June 2018

Pázmándi T., Pántya A., Andrási A. (2018b): New technical recommendations and intercomparison for monitoring individuals for occupational intakes of radionuclides, 43rd Annual Meeting on Radiation Protection, Hajdúszoboszló, Hungary, April 2018 (in Hungarian).

13. Annexe 1: List of participants

First Name	Family Name	Institute	City	Country
Maysoun	Al Maghrabi	Atomic Energy Commission of Syria	Damascus	Syrian Arab Republic
Pablo	Andres	Div. Prot. Radiológica - Centro Atómico Bariloche	San Carlos De Bariloche	Argentina
Cheryl	Antonio	MSA/DOE Hanford	Richland	USA
Frank	Assenmacher	Paul Scherrer Institut	Villigen Psi	Switzerland
Céline	Baillon	IRSN	Le Vesinet	France
Leonardo	Baldassarre	L.B. Servizi per le Aziende Srl	Roma	Italy
Frik	Beeslaar	NECSA	Pretoria	South Africa
Philippe	Berard		Paris	France
Derek	Bingham	AWE Plc	Aldermaston, Reading	United Kingdom
Eric	Blanchardon	IRSN	Fontenay-Aux-Roses	France
Nicolas	Blanchin	CEA	Saint Paul Lez Durance	France
Bastian	Breustedt	Karlsruhe Institute Of Technology	Eggenstein-Leopoldshafen	Germany
Borut	Breznik	Nuclear Power Plant Krsko	Krsko	Slovenia
Richard	Bull	NUVIA Ltd	Didcot	United Kingdom
Cécile	Challeton-De Vathaire	IRSN	Fontenay-Aux-Roses	France
Gian Marco	Contessa	ENEA	Frascati (Roma)	Italy
Estelle	Davesne	IRSN	Fontenay-Aux-Roses	France
Lina	Ekerljung	Forsmarks Kraftgrupp Ab (FKA)	Östhammar	Sweden
Massimo	Esposito	U-Series Srl	Bologna	Italy
Alexandra	Faussart	Commissariat à l'Energie Atomique - Cadarache	Saint Paul Lez Durance	France
María Luz	Fernández	National Commission of Atomic Energy, Argentina	Ezeiza	Argentina
Pavel	Fojtík	SURO (NRPI)	Praha 4	Czech Republic
Martina	Froning	Forschungszentrum Jülich Gmbh	Jülich	Germany
Evgeniya	Granovskaya	State Research Center - Burnasyan Federal Medical	Moscow	Russia

		Biophysical Center of Federal Medical Biological Agency		
Fabio	Gueli	Joint Research Centre of Ispra - European Commission	Ispra (VA)	Italy
Wi-Ho	Ha	Kirams (Korea Institute of Radiological And Medical Sciences)	Seoul	Republic Of Korea
Michael	Hajek	International Atomic Energy Agency	Vienna	Austria
Svend	Hvidsten	Odense University Hospital (Ouh)	Odense	Denmark
Laurence	Jones	INM	Gosport	United Kingdom
Majid	Khalaf	Lawrence Livermore National Laboratory (LLNL)	Livermore, Ca	USA
Evgeniia	Korneva	State Research Center - Burnasyan Federal Medical Biophysical Center of Federal Medical Biological Agency	Moscow	Russia
Tuvia	Kravchik	NRCN	Beer Sheva	Israel
Traudl	Krec	AREVA Gmbh	Erlangen	Germany
Stephanie	Lamart	CEA	Arpajon	France
Madeleine	Lees	Devonport Royal Dockyard Limited	Plymouth	United Kingdom
Chunsheng	Li	Health Canada	Ottawa	Canada
Fabiana	Lima	Centro Regional de Ciências Nucleares do Nordeste - CRCN-NE/CNEN	Recife	Brazil
Daniela	Loehnert	VKTA	Dresden	Germany
Maria Antonia	Lopez	CIEMAT	Madrid	Spain
Francesco	Mancini	SOGIN	Roma	Italy
Matteo	Mariselli	Azienda Ospedaliera "Ospedali Riuniti Marche Nord"	Pesaro (PU)	Italy
James	Marsh	PHE	Didcot, Oxon	United Kingdom
Oliver	Meisenberg	German Federal Office for Radiation Protection (BfS)	Oberschleissheim	Germany
Maarit	Muikku	STUK-Radiation and Nuclear Safety Authority	Helsinki	Finland
Jorn	Nybo	Medicotechnical Institute	Kolding	Denmark
Gregor	Omahen	Zvd Zavod Za Varstvo Pri Delu	Ljubljana Polje	Slovenia
Jakub	Ośko	National Centre For Nuclear Research	Otwock	Poland
Anna	Pantya	Hungarian Academy of Sciences, Centre for Energy Research	Budapest	Hungary
Mark	Peace	Sellafield Ltd	Seascale	United Kingdom
Alessandro	Porta	Politecnico di Milano	Milano	Italy

Marco	Ramos	Eletrobrás Eletronuclear	Angra Dos Reis	Brazil
Arlene	Reis	Instituto de Radioproteção e Dosimetria	Rio De Janeiro	Brazil
Henrik	Roed	Danish Health Authority	Herlev	Denmark
Clemens	Scholl	LIA.Nrw	Duesseldorf	Germany
David	Spencer	NUVIA Limited, Dounreay	Thurso	United Kingdom
Luciano	Sperandio	ENEA	Roma	Italy
Gabriella	Taba	Semmelweise University	Budapest	Hungary
Kotaro	Tani	NIRS, QST	Chiba	Japan
Mattia	Taroni	Kaos Srl	Ferrara	Italy
Bertrand	Thériault	Canadian Nuclear Safety Commission	Ottawa (Ontario)	Canada
Ausra	Urboniene	Radiation Protection Centre	Vilnius	Lithuania
Ignazio	Vilardi	ENEA	S.M. Galeria - Rome	Italy
Vadim	Vostrotin	Southen Urals Biophysics Institute	Ozersk	Russia
Giacomo	Zambelli	Protex Italia Srl	Forlì	Italy
Jianfeng	Zhang	National Institute For Radiological Protection, Chinese Center for Disease Control and Prevention (Nirp, China Cdc),	Beijing	China
Maurizio	Zuccoli		Vedano Olona (VA)	Italy

14. Annexe 2: Data received from participants

14.1 Results from participants, Case 1

PID	Accredited	Estimation with ICRP				OIR			
		Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software	Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software
1	Yes	1.07E+04	1.65E-08	0.176	IMBA Expert UK edition 4.1.9	2.60E+04	3.10E-08	0.807	
2	No	2.94E+04	1.70E-08	0.5	IMBA Pro+ 4.0.36	3.10E+04	3.10E-08	0.96	
3	Yes	3.10E+04	1.78E-08	0.53		3.10E+04	3.10E-08	0.961	
4	No	2.80E+04	1.65E-08	0.46	IMBA Pro+ 4.1.55 (ICRP 68)				
8	Yes	1.15E+04	1.62E-08	0.19	IMBA Pro+ 4.1.31	2.25E+04	3.10E-08	0.698	
9	Yes	3.10E+04	1.70E-08	0.527	AIDE 6	3.10E+04	3.10E-08	0.96	
10	No	3.10E+04	1.65E-08	0.512	IMBA Pro+ 4.1.44	3.10E+04	3.10E-08	0.961	
11	No	3.10E+04	1.70E-08	0.527	AIDE 6	3.28E+04	6.20E-09	0.204	
12	Yes	2.97E+04	1.70E-08	0.51		2.83E+04	3.10E-08	0.88	
13	Yes	3.78E+04	1.70E-08	0.642	IMBA Pro+ 4.0.42	2.58E+04	3.10E-08	0.439	
14	Yes	3.10E+04	1.65E-08	0.51	IMBA Pro+ 4.0	2.90E+04	3.10E-08	0.89	
15	Yes	3.10E+04	1.70E-08	0.53		3.10E+04	3.10E-08	0.96	
16	Yes	3.10E+04	1.70E-08	0.526		3.10E+04	3.10E-08	0.962	
21	No	3.13E+04	1.70E-08	0.53	Mondal 3.01	3.11E+04	3.10E-08	0.96	
22	No	3.11E+04	1.70E-08	0.963		3.11E+04	3.10E-08	0.528	
23	No	3.10E+04	1.62E-08	0.5	IMBA 4.1.52	2.80E+04	3.10E-08	0.87	
24	Yes	2.73E+04	1.65E-08	0.45	IMBA Pro+ 4.1.18	2.78E+04	3.10E-08	0.86	
25	Yes	3.78E+04	1.70E-08	0.64	MS Excel 2010	3.03E+04	3.10E-08	0.94	MS Excel 2010
26	Yes	3.78E+04	1.70E-08	0.624	IMBA Pro+ update 4.1	3.10E+04	3.10E-08	0.96	
27	Yes	3.80E+04	1.70E-08	0.64		3.00E+04	3.10E-08	0.94	

PID	Accredited	Estimation with ICRP				OIR			
		Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software	Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software
28	No	3.10E+04	0.00E+00	0.511	IMBA Pro+ Ver 4.1	3.11E+04	3.10E-08	0.963	
30	Yes	3.78E+04	1.70E-08	0.642		3.10E+04	3.10E-08	0.961	
31	No	3.00E+04	7.10E-09	0.214	IMBA 4.1.55	3.38E+04	6.20E-09	0.21	
33	No	3.30E+04	1.70E-08	1	Excel	2.80E+04	3.10E-08	0.86	Excel
34	Yes	3.10E+04	1.70E-08	0.527		3.09E+04	3.10E-08	0.958	
35	No	3.78E+04	1.70E-08	0.64		2.42E+04	3.10E-08	0.75	
36	Yes	2.87E+04		0.205	IMBA Pro+ 4.0.65	3.11E+04	3.10E-08	0.963	
38	No	3.13E+04	1.70E-08	0.530		3.11E+04	3.10E-08	0.96	
39	Yes	2.80E+04	1.70E-08	0.48		2.80E+04	3.10E-08	0.88	
40	No	3.10E+04	1.70E-08	0.527	AIDE 6	3.10E+04	3.10E-08	0.961	
41	No	3.78E+04	1.70E-08	0.642		3.05E+04	3.10E-08	0.946	
42	Yes	3.10E+04	1.70E-08	0.512	IMBA 4.1.60	3.06E+04	3.10E-08	0.95	BIOKMOD
44	Yes	3.01E+04	1.65E-08	0.5	IMBA Pro+ 4.0	3.37E+04	3.10E-08	1.04	
46	Yes	3.78E+04	1.70E-08	0.64		2.58E+04	3.10E-08	0.8	Excel 2010 solver tool
47	No	2.78E+04	1.60E-08	0.45	CALIN V2 01	3.10E+04	3.10E-08	0.96	
48	No	3.78E+04	1.70E-08	0.64		3.03E+04	3.10E-08	0.94	
50	Yes	2.80E+04	1.70E-08	0.46	IMBA Pro+ 4.1.61				
51	No	3.78E+04	1.70E-08	0.64		3.01E+04	3.10E-08	0.93	
53	No	3.33E+04	1.70E-08	0.57		3.10E+04	3.10E-08	0.96	
55	No	3.78E+04	1.70E-08	0.642		2.58E+04	3.10E-08	0.799	
57	No	1.87E+04	1.70E-08	0.319†	MONDAL 3.01	2.88E+04	3.10E-08	0.894†	
58	No	3.10E+04	1.70E-08	0.527	AIDE 6.0	3.02E+04	3.10E-08	0.935	
60	Yes	4.87E+03	1.65E-08	0.08	IMBA 4.1.55	2.80E+04	3.10E-08	0.87	
62	No	3.78E+04	1.70E-08	0.642		3.07E+04	3.10E-08	0.951	
63	No	1.31E+04	1.70E-08	0.222	OPSCI 2.3				

PID	Accredited	Estimation with ICRP				OIR			
		Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software	Intake [Bq]	DCF [Sv/Bq]	Committed Effective Dose [mSv]	Software
64	No	3.78E+04	1.70E-08	0.64	MONDAL 3	2.70E+04	3.10E-08	0.84	
65	Yes	3.78E+03	1.65E-08	0.619	IMBA 4.1	3.05E+04	3.10E-08	0.944	IMBA 4.1
68	Yes	3.80E+04	1.70E-08	0.64		3.00E+04	3.10E-08	0.93	
70	Yes	3.02E+04	1.70E-08	0.51	IMBA Pro+ 4.1.55	3.11E+04	3.10E-08	0.96	
71	No	3.10E+04	1.70E-08	0.53		3.10E+04	3.10E-08	0.96	
72	No	3.10E+04	1.70E-08	0.526		3.37E+04	3.10E-08	1.04	
73	No	3.13E+04	1.70E-08	0.59	IDEASYSTEM	2.80E+04	3.10E-08	0.48	
74	No	3.10E+04	1.70E-08	0.53		2.90E+04	3.10E-08	0.91	
75	No	3.10E+04	1.70E-08	0.53	IMBA Pro+ 4.1.61	3.10E+04	3.10E-08	0.96	
76	No	3.15E+04	1.70E-08	0.54		3.15E+04	3.10E-08	0.989	
77	No	3.10E+04	1.70E-08	0.528†		2.90E+04	3.10E-08	0.91	
78	No	3.42E+04	1.70E-08	0.58		3.00E+04	3.10E-08	0.93	
79	No	3.78E+04	1.70E-08	0.642	IMBA	2.59E+04	3.10E-08	0.804	
80	No	3.11E+04	1.63E-08	0.51	IMBA 4.1.23	2.59E+04	3.10E-08	0.8	Excel
81	Yes	2.49E+04	1.65E-08	0.412	IMBA 4.1.55	3.11E+04	3.10E-08	0.96	
84	Yes	3.07E+04	1.65E-08	0.506	IMBA Pro+ 4	3.10E+04	3.10E-08	0.96	

†Submitted data were expressed in Sv and not mSv, they have been corrected.

14.2 Results from participants, Case 2

PID	Accredited	Type of Intake (A: Acute; C: Chronic; A=0: Acute set at zero, C=0 : Chronic set at zero)						Total Intake [Bq]	Used DCF [Sv/Bq]	Total Committed Effective Dose [mSv]	Software
		#1	#2	#3	#4	#5	#6				
1	Yes	A	A	A=0	A=0	A=0	A	8.53E+05	7.32E-09	6.24	IMBA Expert UK 4.1.9
2	No	C	A	–	–	–	C	4.62E+05	1.37E-08	6.34	
3	Yes	A	A	–	–	–	A	4.71E+05	1.40E-08	6.6	
4	No	C	A	–	–	–	–	8.42E+05	7.30E-09	6.17	IMBA Pro+ 4.1.55
8	No	C	A	–	–	–	–	8.40E+05	7.32E-09	6.2†	IMBA Pro+ 4.1.31
9	Yes	A	A	A	A	–	–	8.49E+05	7.30E-09	6.20	
10	No	A	A	A	–	–	–	1.10E+06	1.40E-08	11.7	IMBA Pro+ 4.1.44
11	No	A	A	A	A	A	A	1.39E+06	7.30E-09	10.1	
12	Yes	C	A	C	C	C	C	1.01E+06	1.40E-08	14.1	
13	Yes	A	A	–	–	A	A	4.74E+05	1.40E-08	6.52	IMBA Pro+ 4.0.42
14	No	A	A	A	A	–	–	4.84E+05	1.37E-08	6.62	IMBA Pro+ 4.0
15	Yes	A	A	A	A	–	–	4.79E+05	1.40E-08	6.7	
16	Yes	A	A	A=0	A	–	–	8.55E+05	7.30E-09	6.24	
21	No	C	A	C	C	C	C	4.70E+05	1.40E-08	6.59	Mondal 3.01
22	No	C	A	C	C	C	C	1.54E+06	7.03E-09	11.2	
23	No	A	A	A	–	–	–	9.07E+05	7.32E-09	6.64	IMBA 4.1.52
24	Yes	A	A	A	A	–	–	4.89E+05	1.37E-08	6.5	IMBA Pro+ 4.1.18
25	Yes	A	A	A	A	–	–	9.93E+05	7.30E-09	7.25	MS Excel 2010
26	Yes	A	A	A=0	A	–	–	4.56E+05	1.40E-08	6.39	IMBA Pro+ update
28	No	C	C	A	C	C	C	8.68E+05		6.35	IMBA PRO 5
30	Yes	A	A=0	A	A=0	A	–	4.58E+05	1.40E-08	6.41	
31	No	C	A	C=0	C	C	C	9.01E+05	7.30E-09	6.58	IMBA 4.1.55
33	No	A	A	–	–	A	A	8.92E+05	7.30E-09	6.51	Excel
35	No	A	A	–	A	A	A	9.17E+05	7.30E-09	6.69	

PID	Accredited	Type of Intake (A: Acute; C: Chronic; A=0: Acute set at zero, C=0 : Chronic set at zero)						Total Intake [Bq]	Used DCF [Sv/Bq]	Total Committed Effective Dose [mSv]	Software
		#1	#2	#3	#4	#5	#6				
36	Yes	C	C	C	C	—	—	8.30E+05	as at software	6.00	IMBA Pro+ 4.0.65
40	No	A	A	—	—	—	A	4.71E+05	1.40E-08	6.6	AIDE 6
41	No	A	A	A	A	—	—	9.15E+05	7.30E-09	6.678	-
42	Yes	A	A	A	A	—	—	8.87E+05	7.30E-09	6.49	AIDE 6.0 IMBA 4.1.60
44	Yes	A	A	—	—	—	A	4.70E+05	1.37E-08	6.44	IMBA Pro+ 4.0
46	Yes	A	A	—	A	—	—	4.56E+05	1.40E-08	6.25	IMBA Pro+ 4.1.50
47	No	C	C	C	A	A	C	8.37E+05	7.30E-09	6.12	CALIN 2 01
48	No	A	A	—	—	—	—	9.11E+05	7.30E-09	6.7	
51	No	C	A	—	—	—	—	4.58E+05	1.40E-08	6.41	
53	No	C	A	C	C	—	—	4.86E+05	1.40E-08	6.8	
54	No	A	A	—	—	A	A	4.95E+05	1.39E-08	6.9	AIDE 6
55	Yes	A	A	A=0	A	—	—	4.47E+05	1.40E-08	6.25	DCAL 9.02
57	No	A	A	—	—	A	—	4.74E+05	1.40E-08	6.63	-
58	No	A	A	—	—	—	A	4.71E+05	1.40E-08	6.6	AIDE 6
60	Yes	A	A	A	A	—	—	1.85E+06	1.37E-08	6.48	IMBA 4.1.55
62	No	A	A	A	A	—	—	3.20E+05	1.40E-08	4.47	
63	No	A	A	C=0	C=0	A	A	1.02E+06	7.03E-09	7.44	
64	No	C	A	—	—	—	C	8.51E+05	7.30E-09	6.26	
65	Yes	A	A	A=0	A=0	A=0	A	4.50E+05	1.37E-08	6.15	IMBA 4.1
70	Yes	A	A	—	—	—	A	3.99E+05	1.40E-08	5.58	IMBA Pro+ 4.1.55
71	No	C	A	C	C	C	C	8.68E+05	7.30E-09	6.3	Mondal 3.01
72	No	C	A	A=0	A=0	C=0	C=0	4.36E+05	1.40E-08	6.1	
73	No	A	A	—	—	A	A	9.18E+05	7.30E-09	6.7	
74	No	A	A	A	A	A	A	7.00E+05	1.40E-08	9.9	
75	No	A	A	A	A	—	—	8.80E+05	7.30E-09	6.4	IMBA Pro+ 4.1.61

PID	*Accredited*	*Type of Intake (A: Acute; C: Chronic; A=0: Acute set at zero, C=0 : Chronic set at zero)*						*Total Intake [Bq]*	*Used DCF [Sv/Bq]*	*Total Committed Effective Dose [mSv]*	Software
		#1	*#2*	*#3*	*#4*	*#5*	*#6*				
76	No	A	A	A	A	A	A	7.05E+05	1.40E-08	9.86	
77	No	A	A	A	A	A	A	7.00E+05	1.40E-08	9.9	
78	No	A	A	–	A	–	–	1.16E+06	7.30E-09	8.44	
79	No	A	A	–	–	–	A	9.44E+05	7.30E-09	6.89	
80	No	C	C	–	–	–	C	4.55E+05	1.37E-08	6.23	IMBA 4.1.23
81	Yes	A	A	A	A	A	–	8.79E+05	1.37E-08	6.43	IMBA 4.1.55
84	Yes	A	A	A=0	A	–	–	8.53E+05	7.32E-09	6.24	IMBA Pro+ 4

[†]Submitted datum was expressed in Sv and not mSv, it has been corrected.

14.3 Results from participants, Case 3

PID	Accredited	Initial					Final						Software
		Pathway	Mode	Lung absorption (inhalation only)	Total Intake [Bq]	Total Committed Effective Dose [mSv]	Pathway	Mode	Lung absorption (inhalation only)	AMAD [µm]	Total Intake [Bq]	Total Committed Effective Dose [mSv]	
1	Yes	Inhal	Acute	S	879	5.60	Inhal	Acute	S	5	1521	9.70	IMBA Expert UK Edition 4.01.09
2	No	Ingest	Acute	–	2800	0.02	Inhal	Acute	S	5	1380	8.80	IMBA Pro+ 4.0.36
3	Yes	Inhal	Acute	S	879	5.62	Inhal	Chronic	S	5	633	4.04	IMBA Pro+ 4.0.13
8	Yes	Inhal	Chronic	S	354	4.80	Ingest	–	–	–	0	0.00	IMBA Pro+ 4.1.31
9	Yes	Inhal	Acute	S	1240	7.84	Inhal	Acute	S	5	1240	7.84	
11	No	Inhal	Acute	S	393	2.24	Inhal	Acute	S	5	542	3.43	AIDE 6
12	Yes	Inhal	Chronic	S	450	2.84	Inhal	Chronic	S	5	950	6.00	
13	Yes	Inhal	Acute	S	871	5.50	Inhal	Chronic	S	5	648	4.21	IMBA Pro+ 4.0.42
14	No	Inhal	Acute	S	879	5.62	Injection or wound	Acute	–	5	93	0.17	IMBA Pro+ 4.1.50
15	Yes	Inhal	Acute	S	893	5.64	Inhal	Acute	S	5	1430	9.07	
16	No	Inhal	Acute	S	893	5.64	Inhal	Acute	S	5	1520	9.71	
23	No	Inhal	Acute	S	895	5.68	Inhal	Chronic	S	5	594	3.80	IMBA 4.1.52
24	Yes	Inhal	Acute	S	879	6.00	Ingest	Acute	–	–	787	0.04	IMBA Pro+ 4.1.18
25	Yes	Inhal	Acute	S	703	4.50	Inhal	Acute	S	5	1150	7.36	MS Excel 2010 IMBA Pro+ 4.1.18
26	Yes	Inhal	Acute	S	879	5.54	Ingest	Acute	–	–	2080	0.10	IMBA Pro+update
27	Yes	Inhal	Acute	S	919	5.80	Inhal	Chronic	S	5	665	4.29	
28	No	Inhal	Chronic	S	340	2.16	Inhal	Chronic	S	5	580	3.71	IMBA Pro+ 5
31	No	Inhal	Acute	S	921	5.84	Inhal	Chronic	S	5	883	5.48	IMBA 4.1.55
33	No	Ingest	Acute	–	2420	0.02	Ingest	Chronic	–	–	577	0.005	Excel
41	No	Inhal	Acute	S	662	4.15	Inhal	Acute	S	5	1615	10.30	IMBA 4.0.34
42	Yes	Inhal	Acute	S	881	5.57	Inhal	Acute	S	5	1500	9.56	IMBA 4.1.60

PID	Accredited	Initial					Final						Software
		Pathway	Mode	Lung absorption (inhalation only)	Total Intake [Bq]	Total Committed Effective Dose [mSv]	Pathway	Mode	Lung absorption (inhalation only)	AMAD [µm]	Total Intake [Bq]	Total Committed Effective Dose [mSv]	
44	Yes	Inhal	Acute	S	921	5.84	Inhal	Chronic	S	5	856	5.50	IMBA Pro+4.0
46	Yes	Inhal	Acute	S	708	4.50	Inhal	Acute	S	5	1561	10.00	IMBA Pro+ 4.1.50
47	No	Inhal	Chronic	M	11	0.02	Inhal	Acute	M	5	23	0.04	CALIN V2 01
49	Yes	Inhal	Acute	S	920	6.40	Inhal	Acute	S	5	1481	9.50	IMBA Pro+ 4.1.11
55	Yes	Inhal	Acute	S	687	4.33	Inhal	Acute	S	5	1830	11.70	DCAL 9.2
57	No	Inhal	Acute	S	900	5.68	Inhal	Acute	S	5	1070	8.10	MONDAL 3.01
60	Yes	Inhal	Acute	S	921	5.90	Inhal	Chronic	S	5	500	3.20	IMBA 4.1.55
62	No	Ingest	Acute	—	182	0.01	Inhal	Chronic	S	5	400	2.54	
65	Yes	Inhal	Acute	S	914	5.79	Inhal	Acute	S	5	1561	10.00	IMBA 4.1
67	No	Inhal	Chronic	S	719	4.53	Inhal	Chronic	S	5	314	2.78	MMK-02 4/3.1
70	Yes	Inhal	Chronic	M	38	0.07	Injection or wound	Acute	—	—	75	0.15	IMBA Pro+ 4.1.55
75	No	Inhal	Acute	S	850	5.40	Inhal	Acute	S	5	1500	9.70	IMBA Pro+ 4.1.61
77	No	Inhal	Acute	F	2	0.00	Inhal	Chronic	F	5	3	0.003	MONDAL 3
78	No	Inhal	Acute	S	899	5.68	Inhal	Acute	S	0.3	699	7.84	
80	No	Inhal	Acute	S	912	5.77	Inhal	Acute	S	5	1260	8.09	IMBA 4.1.23
81	Yes	Inhal	Acute	S	921	5.90	Inhal	Chronic	S	5	498	3.21	IMBA 4.1.55
84	Yes	Inhal	Acute	S	921	5.83	Inhal	Acute	S	5	1845	11.80	IMBA Pro+ 4

14.4 Results from participants, Case 4

Table A

PID	Accredited	Factors								Total number of data considered		SF of Type-B uncertainty		Correction due to DTPA treatment
		AMAD [μm]	F [%]	M [%]	S [%]	f_r	s_r [1/d]	s_s [1/d]	f_1 or f_A	Urine	Lung	Lung	Urine	
1	Yes	5	0	100	0				0.0005	6	19	1.25	1.6	No
2	No	5	0	100	0	0.54	0.47	0.0022	0.0005	6	7	1.25	1.6	Yes
3	Yes	0.5	0	100	0			0.012	0.0005	9	13	1.5	1.6	No
8	Yes	10	0	100	0				0.0005	11	19	1.4	1.6	No
9	Yes	5	0	100	0					16	19	2.06	1.6	Yes
12	Yes	1	0	100	0				0.0005	22	2			
13	No	5	0	0	0	0.8	0.02	0.0001	0.0005	11	21	1.25	1.6	Yes
14	No	5	89	0	11				0.0005	16	19			Yes
20		5	0	0	0	0.8	0.02	0.00001	0.0005	11	21	-	1.8	No
23	No	5	0	100	0				0.0005	12	21	1.4	1.6	Yes
24	Yes	5	0	100	0				0.0005	12	21	1.25	1.6	No
25	Yes	10	0	100	0				0.0005	10				No
26	Yes	9	0	0	0	0.26	100	0.0025	0.0005	19	19	1.25	1.6	Yes
28	No	5	0	100	0				0.0005	16	7	1.25	1.6	Yes
33	No	5	0	86.4	13.6				0.0005	11	21			No
40	No	5	0	100	0				0.005	11	5	1.3	1.6	Yes
41	No	5	0	100	0	0.05	100	0.004	0.0005	5	16	1.25	2	No
44	Yes	5	0	100	0	0.01	100	0.005	0.0005	15	19	3	3	No
46	Yes	5	26	54	(20)				0.0005	13	19	1.25	1.6	No
47	No	1	0	0	0	0.2	0.4	0.005	0.0001					Yes
55	Yes	5	26	54	(20)				0.0005	15	19	1.25	1.6	No
57	No	5	0	100	0					18	21	1.4	1.75	No
59	No	5	0	100	0				0.0005	6	21			Yes

PID	Accredited	Factors								Total number of data considered		SF of Type-B uncertainty		Correction due to DTPA treatment
		AMAD [μm]	F [%]	M [%]	S [%]	f_r	s_r [1/d]	s_s [1/d]	f_1 or f_A	Urine	Lung	Lung	Urine	
60	Yes	5	0	100	0	0.1	100	0.005	0.0005	7	21	2	2	No
64	No	5	0	74	26					20	19	1.25	2	Yes
65	Yes	5	0	0	0	0.25		0.004	0.0005	6	19	1.25	1.6	No
70	Yes	5	2	98	0				0.0005	11	6	1.25	1.6	No
78	No	10	0	95	5				0.0005	6	7	1.25	1.8	Yes
80	No	5	0	0	0	0.5	0.2	0.003	0.0001	11	21	1.25	1.6	No
81	Yes	5	0	100	0	0.1	100	0.005	0.0005	7	21	2	2	No
84	Yes	5	0	0	0	0.3	100	0.0035	0.0005	11	19	1.25	1.6	Yes

Table B

PID	Lung		Urine			Both		Finally used dose coefficient [Sv/Bq]	Software
	Real intake [Bq]	Total committed effective dose [mSv]	Apparent intake [Bq]	Real intake [Bq]	Total committed effective dose [mSv]	Real / Apparent intake [Bq]	Total committed effective dose [mSv]		
1	12860	349	**8718**		**236**	12150	329	0.0000271	IMBA Expert UK Edition 4.01.09
2	15100	328	**17400**	**19400**	**378**	18500	401	0.0000223	IMBA Pro+ 4.0.36
3	8630	405	8690		408	**8650**	**406**	0.000047	IMBA Pro+ 4.0.13
8	28200	470	28100	41400	469	**28200**	**471**	0.0000167	IMBA Pro+
9	19200	321	23200		625	**19500**	**528**	0.000027	AIDE 6
12	19000	741	**25000**	**22000**	**880**	19600	766	0.000039	
13	18700	349	4100	6100	684	**20800**	**388**	0.0000187	IMBA Pro+ 4.0.42
14	23780	483	14100		383	**21200**	**431**	0.00002	IMBA Pro+ 4.0
20	17900	331		19200	356	**18000**	**333**	0.0000185	IMBA Pro+ 4.1.66
23	**13237**	**359**	14911	15245	413	13933	378	0.0000271	IMBA 4.1.52
24	13500	366	17100	17100	463	**14000**	**379**	0.0000271	IMBA Pro+ 4.1.18
25	22360	413	**36600**	**15370**	**284**	17100	316	0.0000185	IMBA Pro+ 4.1.18
26						**21330**	**81**	0.00000378	IMBA Pro+update
28	12300	334	12000	9970	270	**10200**	**276**	0.000027	IMBA Pro+ 5
33	**15040**	**368**	26300	26300	645			0.0000245	Excel, Dosage (by BfS)
40	20300	549	**10200**	**26900**	**278**	14100	381	0.000027	AIDE 6
41	9082	216		11110	265	**9216**	**220**	0.0000239	IMBA 4.0.34
44	10070	273	11190	11190	303	**10890**	**295**	0.0000271	IMBA Pro+4.0
46	9448	210	5720	5720	550	**12600**	**568**	0.000045	IMBA Pro+ 4.1.50
47	6700	240		11227	405	**8170**	**295**	0.0000361	CALIN V2 01
55	12700	569	5990	5990	547	**12600**	**565**	0.0000405	DCAL 9.2
57	14000	316		5600	127	**6278**	**290**	0.0000462	IMBA Pro+
59	12180	330	32390	10740	291	**11190**	**303**	0.0000271	IMBA Pro+ 4.1.31

PID	*Lung*		*Urine*			*Both*		*Finally used dose coefficient [Sv/Bq]*	Software
	Real intake [Bq]	*Total committed effective dose [mSv]*	*Apparent intake [Bq]*	*Real intake [Bq]*	*Total committed effective dose [mSv]*	*Real / Apparent intake [Bq]*	*Total committed effective dose [mSv]*		
60	13200	360	24500	22500	664	**15400**	**420**	0.000027	IMBA 4.1.55
64	**9510**	**170**		14300	278	10400	189	0.0000226	MONDAL 3
65	12930	528		16820	686	**13410**	**547**	0.0000408	IMBA 4.1
70	18700	513		17400	477	**17400**	**523**	0.00003	IMBA Pro+ 4.1.55
78	37900	624	41600	43600	683	**39000**	**641**	0.0000164	
80	16000	345	14700		315	**15700**	**338**	0.0000215	IMBA 4.1.23
81	13200	359	24500	22500	664	**15400**	**418**	0.000027	IMBA 4.1.55
84	12480	566	7746	15020	680	**12860**	**582**	0.00004527	IMBA Pro+ 4

Best estimate values are marked with **bold**

15. Annexe 3: Robust statistics application.

In this intercomparison exercise new statistical indicators were used for the analysis of the results: the robust mean (indicated with RM) and the robust standard deviation (indicated with RSD), as defined by algorithm A described in Annex C, Section C.3 of ISO 13528:2015 (ISO 2015).

With respect to other indicators used in previous intercomparison exercises, the procedure used for estimating RM and RSD does not discard data identified as outliers. Results submitted during an intercomparison exercise are indeed not expected to follow a given statistical distribution, especially in the presence of new methodologies, participants with less experience or who misunderstood the instructions etc. Data that would be considered outliers according to "classical" statistical tests (based e.g. on normal or log-normal distribution) are thus re-evaluated in order not to disperse the potential information they provide.

The procedure used is the following:

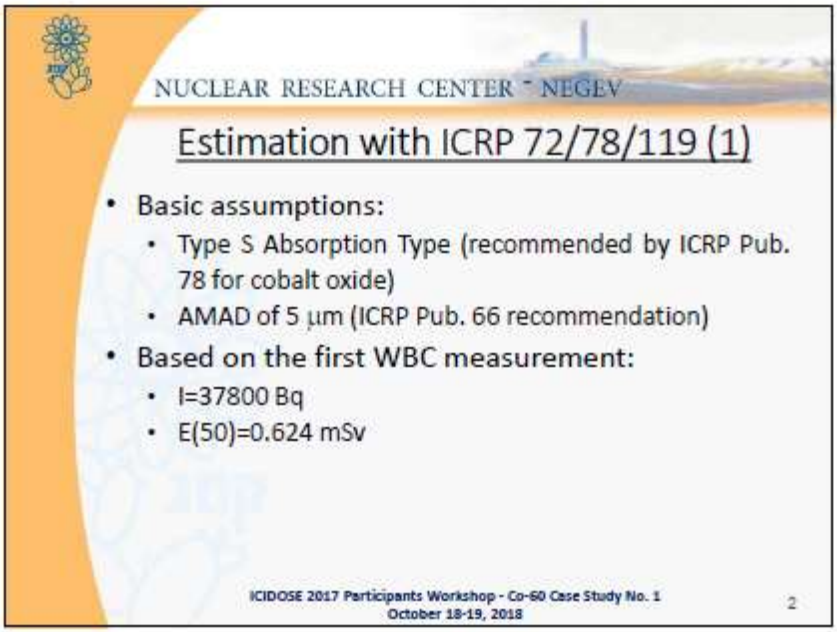
1. An initial estimate of RM (RM_1) is calculated as the median of all submitted results, after having sorted them;
2. An initial estimate of RSD (RSD_1) is calculated as 1.483 multiplied by the median of $|x_i - RM_1|$;
3. A range $RM_1 \pm 1.5 \cdot RSD_1$ is defined. If a given value x_i is outside this range, then this value is forced to fit into the range by replacing it by RM_1-1,5*RSD_1 if its value is above the upper limit of the range or by RM_1+1,5*RSD_1 if its value is above the upper limit of the range, respectively;
4. A new estimate of RM (RM_j, j≥2) is calculated as the arithmetic mean of the new set of x_i;
5. A new estimate of RSD (RSD_j, j≥2) is calculated multiplying the standard deviation of the new set of x_i by a constant factor (1.134);
6. Step 3. is repeated, using RM_j (j≥2) instead of RM_1;
7. Steps 4.-6. are iteratively repeated until no improvement is observed in the estimates of RM and RSD.

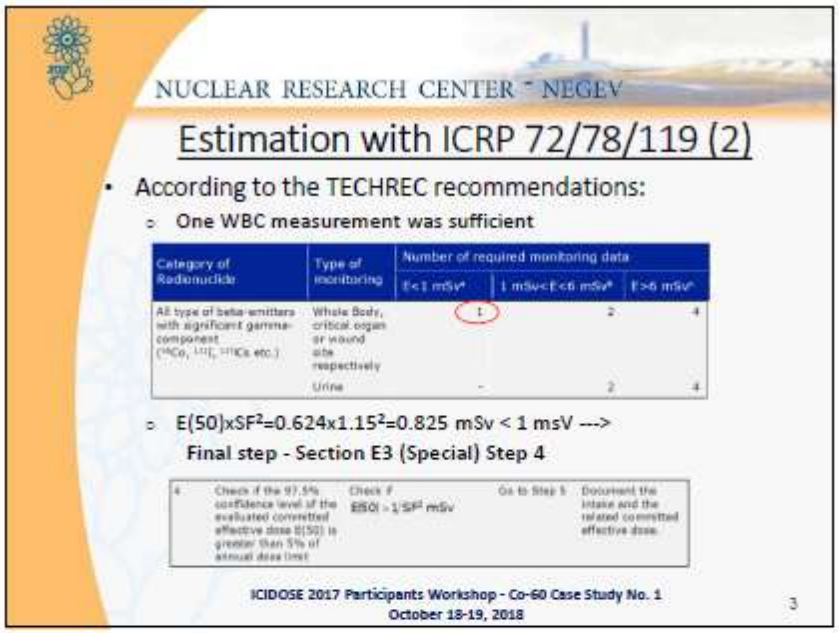
In our analysis the convergence criterion for RM was set at 1E-05 (i.e, the difference between the estimate RM_j (j≥2) and the previous one RM_{j-1} must be less than $1E\text{-}05 \cdot RM_{j-1}$).

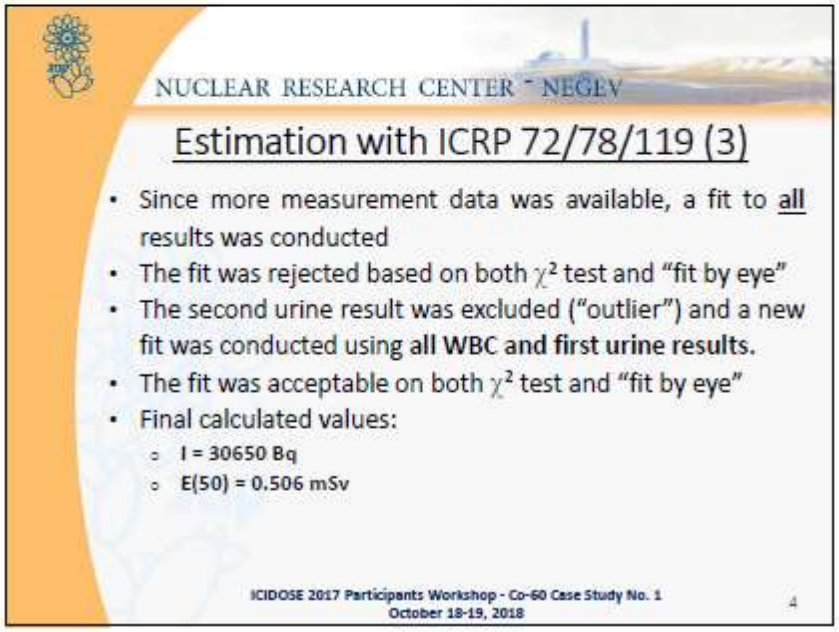
16. Annexe 4: Presentations of solutions to the workshop.

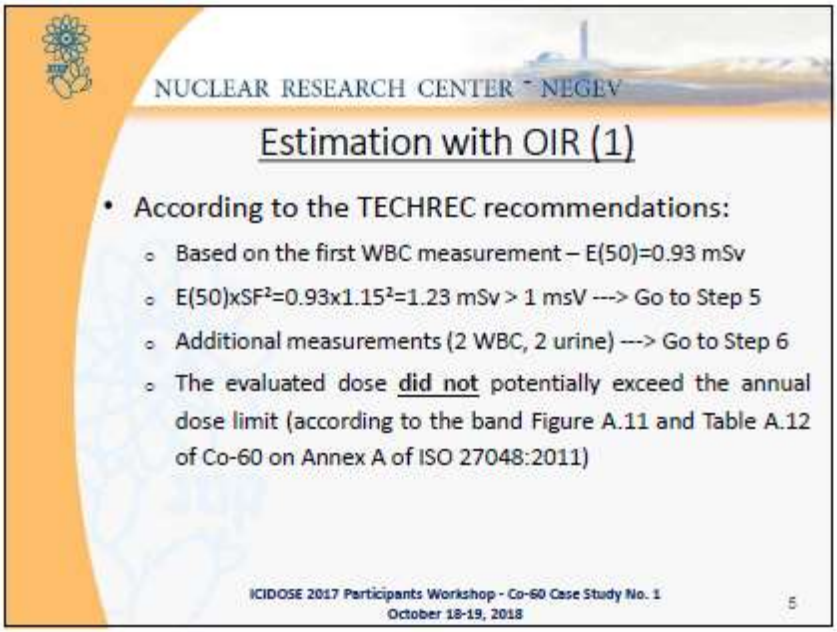
16.1 Presentation related to Case 1

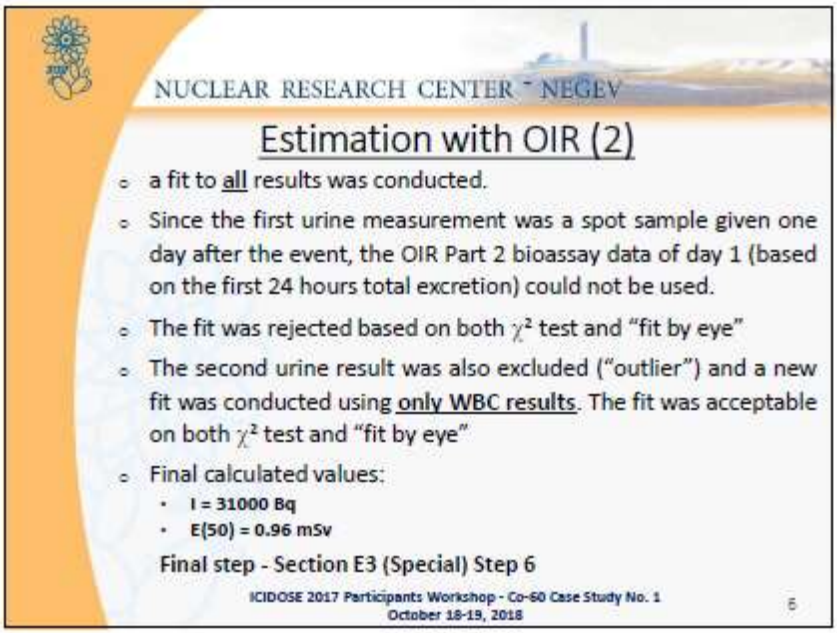
Presentation of Tuvia Kravchik

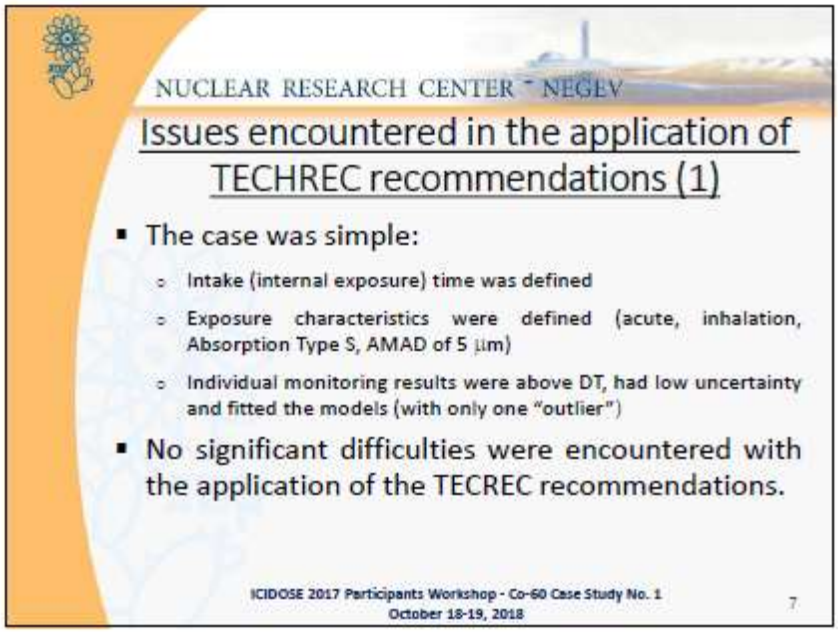


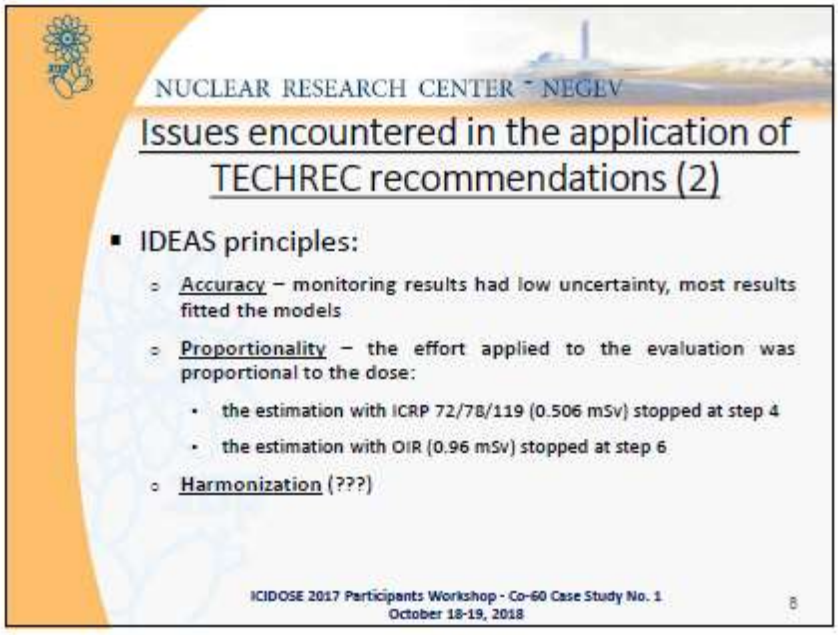

NUCLEAR RESEARCH CENTER - NEGEV
Estimation with ICRP 72/78/119 (2)
• According to the TECHREC recommendations:
○ One WBC measurement was sufficient
Category of Radionuclide
Type of monitoring
Number of required monitoring data
E<1 mSv*
1 mSv<E<6 mSv*
E>6 mSv*
All type of beta-emitters with significant gamma-component (60Co, 131I, 131Cs etc.)
Whole Body, critical organ or wound site respectively
1
2
4
Urine
-
2
4
○ E(50)xSF2=0.624x1.152=0.825 mSv < 1 msV --->
Final step - Section E3 (Special) Step 4
4
Check if the 97.5% confidence level of the evaluated committed effective dose E(50) is greater than 5% of annual dose limit
Check if
E(50) > 1/SF2 mSv
Go to Step 5
Document the intake and the related committed effective dose.
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
3

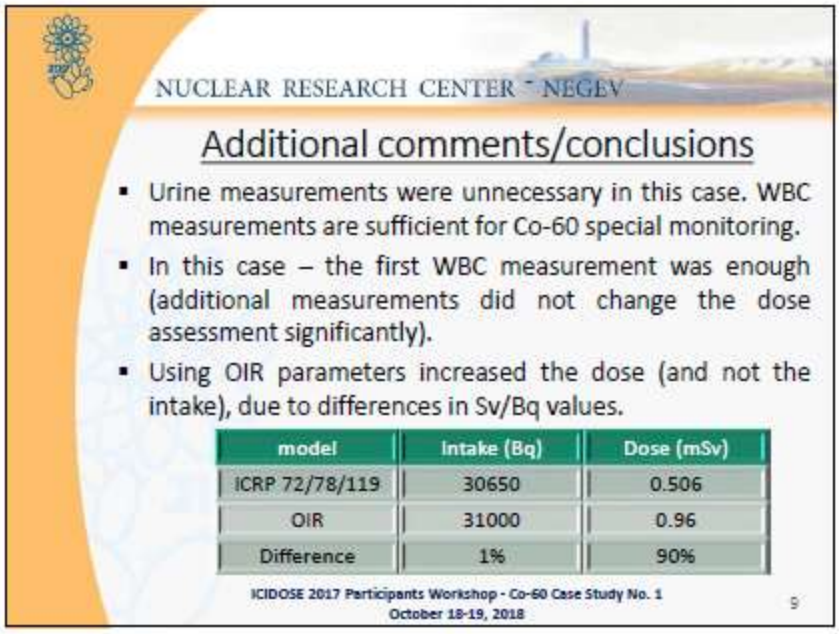

NUCLEAR RESEARCH CENTER - NEGEV
Estimation with ICRP 72/78/119 (3)
• Since more measurement data was available, a fit to all results was conducted
• The fit was rejected based on both χ2 test and "fit by eye"
• The second urine result was excluded ("outlier") and a new fit was conducted using all WBC and first urine results.
• The fit was acceptable on both χ2 test and "fit by eye"
• Final calculated values:
○ I = 30650 Bq
○ E(50) = 0.506 mSv
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
4


NUCLEAR RESEARCH CENTER - NEGEV
Estimation with OIR (1)
• According to the TECHREC recommendations:
◦ Based on the first WBC measurement – E(50)=0.93 mSv
◦ E(50)xSF²=0.93x1.15²=1.23 mSv > 1 msV ---> Go to Step 5
◦ Additional measurements (2 WBC, 2 urine) ---> Go to Step 6
◦ The evaluated dose did not potentially exceed the annual dose limit (according to the band Figure A.11 and Table A.12 of Co-60 on Annex A of ISO 27048:2011)
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
5


NUCLEAR RESEARCH CENTER - NEGEV
Estimation with OIR (2)
◦ a fit to all results was conducted.
◦ Since the first urine measurement was a spot sample given one day after the event, the OIR Part 2 bioassay data of day 1 (based on the first 24 hours total excretion) could not be used.
◦ The fit was rejected based on both χ² test and "fit by eye"
◦ The second urine result was also excluded ("outlier") and a new fit was conducted using only WBC results. The fit was acceptable on both χ² test and "fit by eye"
◦ Final calculated values:
• I = 31000 Bq
• E(50) = 0.96 mSv
Final step - Section E3 (Special) Step 6
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
6

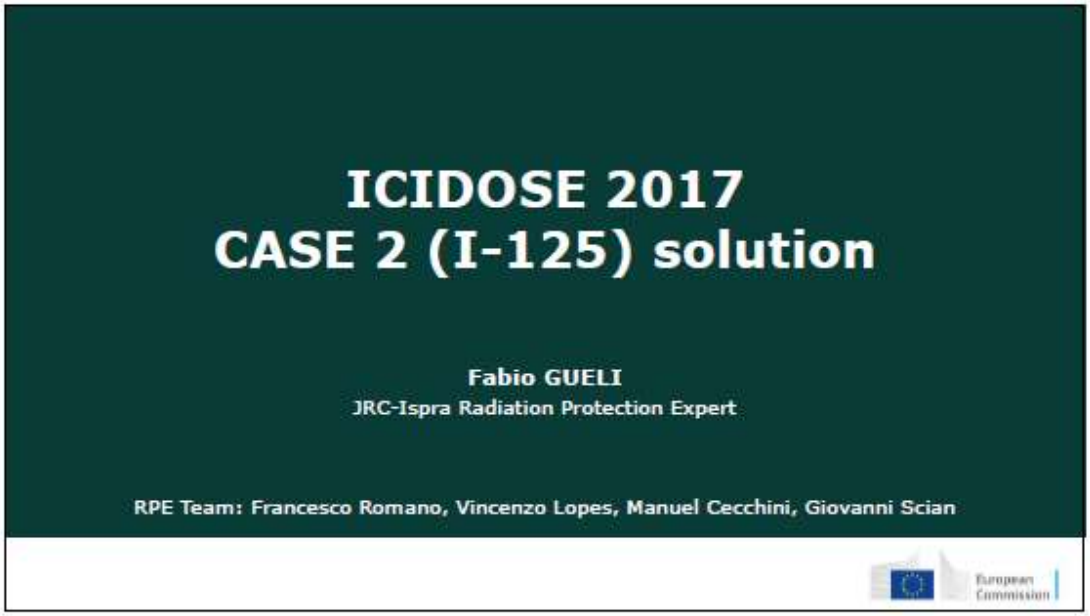

NUCLEAR RESEARCH CENTER - NEGEV
Issues encountered in the application of TECHREC recommendations (1)
The case was simple:
Intake (internal exposure) time was defined
Exposure characteristics were defined (acute, inhalation, Absorption Type S, AMAD of 5 μm)
Individual monitoring results were above DT, had low uncertainty and fitted the models (with only one "outlier")
No significant difficulties were encountered with the application of the TECREC recommendations.
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
7


NUCLEAR RESEARCH CENTER - NEGEV
Issues encountered in the application of TECHREC recommendations (2)
IDEAS principles:
Accuracy – monitoring results had low uncertainty, most results fitted the models
Proportionality – the effort applied to the evaluation was proportional to the dose:
the estimation with ICRP 72/78/119 (0.506 mSv) stopped at step 4
the estimation with OIR (0.96 mSv) stopped at step 6
Harmonization (???)
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
8


NUCLEAR RESEARCH CENTER - NEGEV
Additional comments/conclusions
Urine measurements were unnecessary in this case. WBC measurements are sufficient for Co-60 special monitoring.
In this case – the first WBC measurement was enough (additional measurements did not change the dose assessment significantly).
Using OIR parameters increased the dose (and not the intake), due to differences in Sv/Bq values.
model | Intake (Bq) | Dose (mSv)
ICRP 72/78/119 | 30650 | 0.506
OIR | 31000 | 0.96
Difference | 1% | 90%
ICIDOSE 2017 Participants Workshop - Co-60 Case Study No. 1
October 18-19, 2018
9

16.2 Presentations related to Case 2

Presentation of Fabio Gueli



Key questions

- Chronic Vs Acute intake

  Assumption of Chronic intake in the first and fourth routine monitoring period, acute intake in the second

- Aerosol Vs Vapuor

  Chemical form: suggested lung absorption type F
  Physical characteristic: volatile fraction, not aerosol

Calculation procedure

- 1st calculation method and hypotesis:

  1st period Chronic intake:

  Constant Chronic intake rate calculated as:

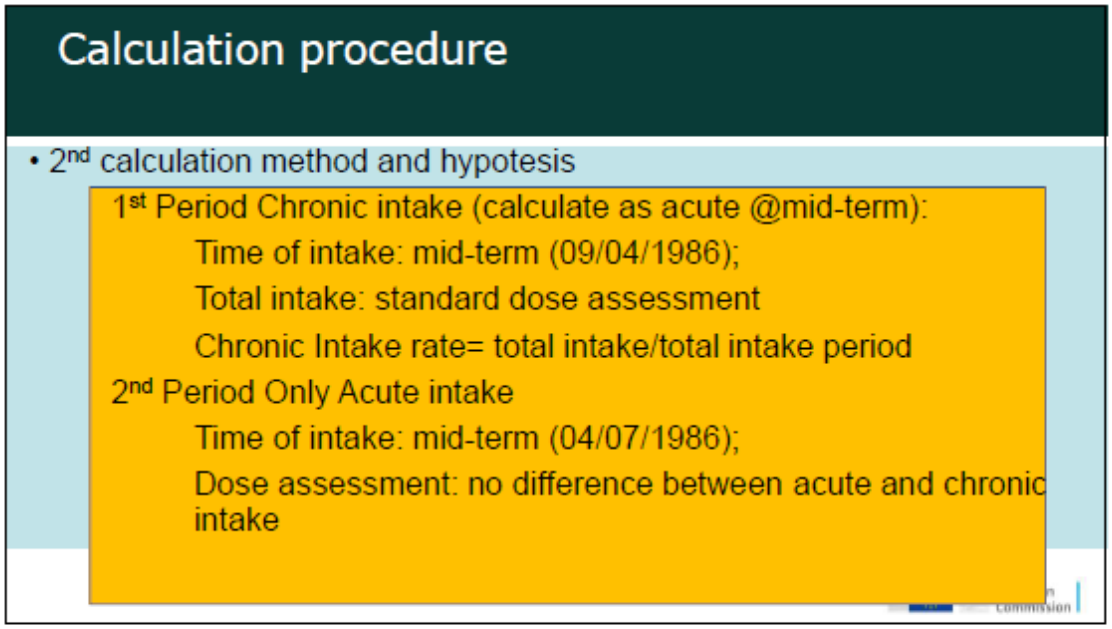
  $$I\left(\frac{Bq}{d}\right) = \frac{M(T)}{\sum_1^T m(t)}$$

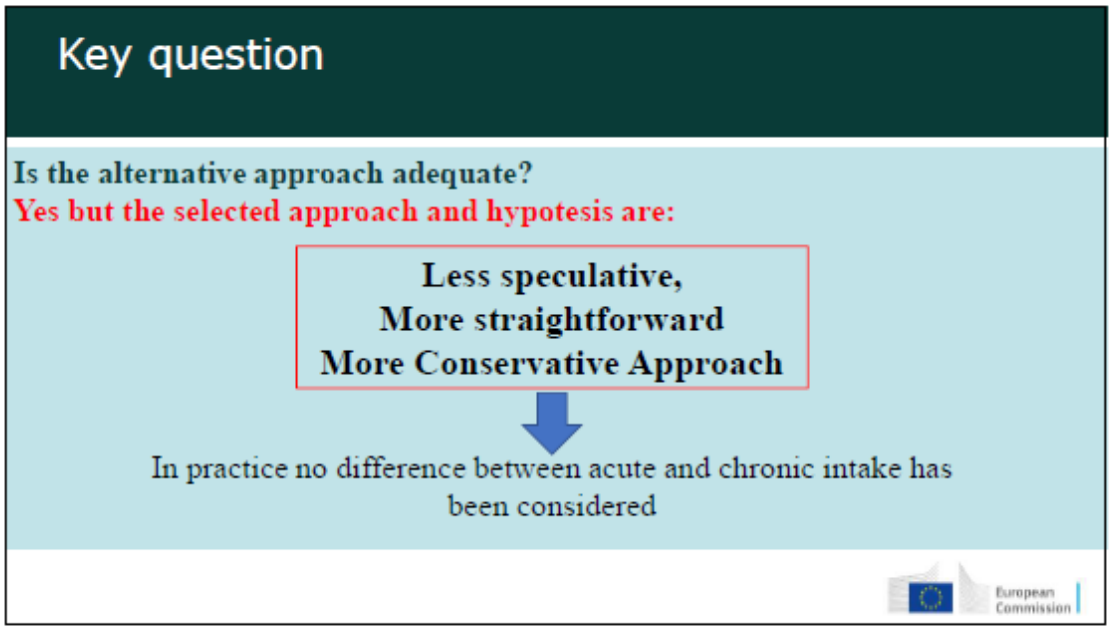
  Total intake= Chronic Intake rate x total intake period

  2nd period Chronic + Acute

  Chronic Intake Rate as for the 1st period (speculative hypotesis)

  Time of acute intake: mid-term (04/07/1986);


Calculation procedure
• 2nd calculation method and hypotesis
1st Period Chronic intake (calculate as acute @mid-term):
Time of intake: mid-term (09/04/1986);
Total intake: standard dose assessment
Chronic Intake rate= total intake/total intake period
2nd Period Only Acute intake
Time of intake: mid-term (04/07/1986);
Dose assessment: no difference between acute and chronic intake


Key question
Is the alternative approach adequate?
Yes but the selected approach and hypotesis are:
Less speculative,
More straightforward
More Conservative Approach
In practice no difference between acute and chronic intake has been considered
European Commission

Calculation procedure

1st Period Chronic intake (calculate as acute @mid-term):

Time of intake: mid-term (09/04/1986);

Total intake: standard dose assessment

Chronic Intake rate= total intake/total intake period

2nd Period Only Acute intake

Time of intake: mid-term (04/07/1986);

Dose assessment: further special measurements required

Calculation procedure

- Special monitoring evaluation:

No further chronic intakes were considered during the special monitoring periods

Evaluation made according to IDEAS guidelines stage 5B step 5.12.3 (Error in reporting)

i.e. the goodness of the three measurements fit is acceptable and the dose is < 6 mSv

CMC1

Calculation procedure

- 5th period analysis (30/9/1986 - 4/12/1986)

SECTION E2 (routine)- STEP 2:

M value exceeds the decision threshold;

M value exceed the critical value (Mc=1.9 E+2 Bq)

The significance of earlier intake contribution has to be checked:

Analysis according to IDEAS guidelines shows that

$$P \cdot SF^2 > M > P / SF^2$$

No intakes are considered in this period

European Commission

Calculation procedure

- 6th period analysis (4/12/1986-28/3/1987)

SECTION E2 (routine)- STEP 2:

As for the 5th period but $M > P \cdot SF^2$

New intake has to be considered

Evaluation made according to 1st period calculation method.

European Commission

CMC2

Results

#	Type of intake			Exposure period (dd/mm/yyyy)		(acute only) Date (dd/mm/yyyy)	(chronic only) Date (dd/mm/yyyy)		Intake value (Bq)	Committed effective dose (mSv)
	None	Acute	Chronic	Beginning	End		from	to		
1	○	○	◉	22/02/1986	25/05/1986		22/02/1986	25/05/1986	5.41E+04	0.385
2	○	◉	○	25/05/1986	13/08/1986	04/07/1986			7.68E+03	5.61
3	◉	○	○	13/08/1986	02/09/1986					
4	◉	○	○	02/09/1986	30/09/1986					
5	◉	○	○	30/09/1986	04/12/1986					
6	○	○	◉	04/12/1986	28/03/1987		04/12/1986	28/03/1987	3.46E+04	0.253

Table 3. Total estimate

Total intake (Bq)	6.57E+05
Used dose coefficient (Sv/Bq)	7.30E-09
Total committed effective dose (mSv)	6.26E+00

European Commission

CMC3

Main issues and considerations

- A structured approach is very useful for establishing and organizing an internal dosimetry service and for correct management of internal contamination situations and dose evaluations
- Complex the simultaneous use of different references (TechRec, ISO, IDEAS) also overlaying each other.
- Problematic the use of the same numbering in the TechRec (E2, E3), clearer sequential numbering of the IDEAS guidelines but more complex in its structure.
- The **Expert** is required only for complex evaluations and with the risk of exceeding the dose limits but strong **Expertise** is always necessary (understanding of the situation and choice of parameters are critical points)

European Commission

Presentation of Clemens Scholl

LIA.nrw

ICIDOSE 2017

I-125 case study

Dr. Clemens Scholl
LIA.nrw
Munich, 19.10.2018

Arbeitsschutz

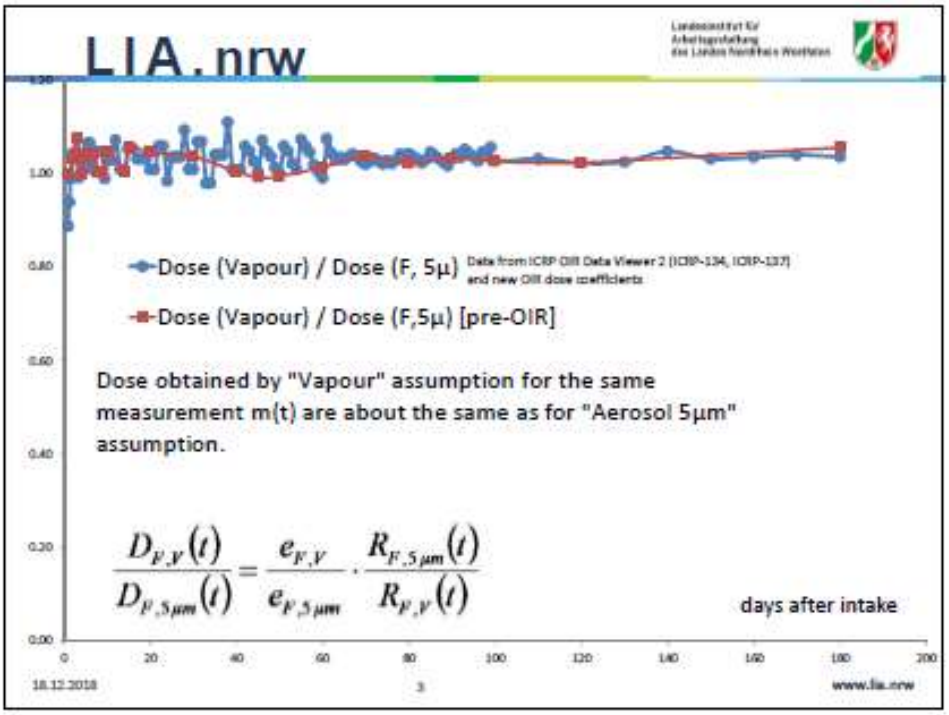
www.lia.nrw

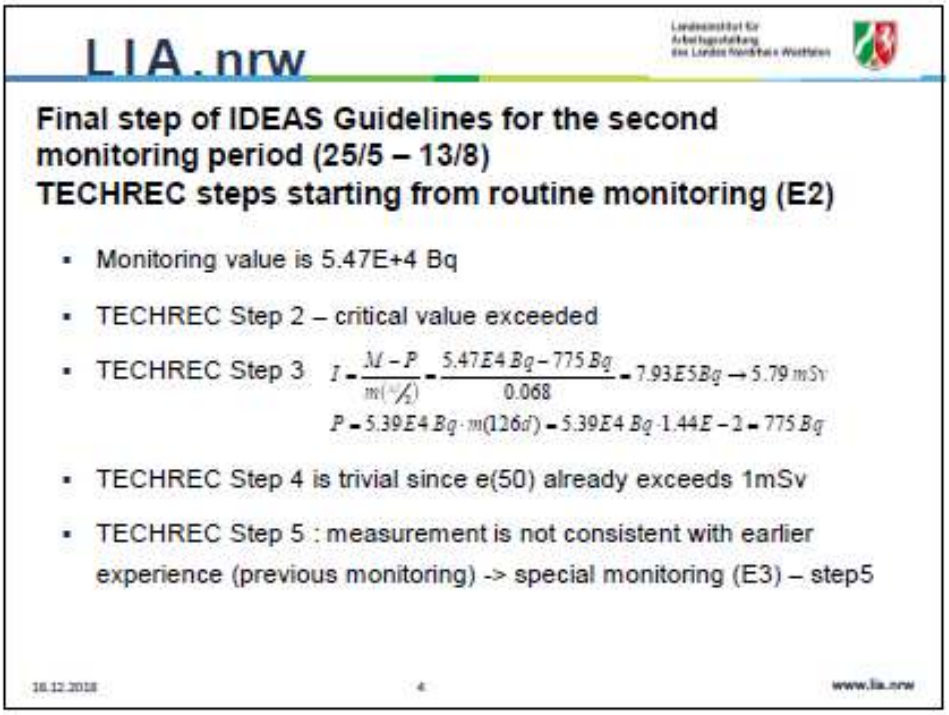
LIA.nrw

Assumption of 5µm AMAD aerosol inhalation as pathway of intake

- Physical characteristics of case description point to „volatile fraction, not aerosol"
- However, routine monitoring uses aerosol type F with 5µm AMAD as default value
- Retention curves and dose coefficients are different, but the doses resulting from assessment are not

18.12.2018 2 www.lia.nrw


LIA.nrw
Dose (Vapour) / Dose (F, 5µ)
Data from ICRP OIR Data Viewer 2 (ICRP-134, ICRP-137) and new OIR dose coefficients
Dose (Vapour) / Dose (F,5µ) [pre-OIR]
Dose obtained by "Vapour" assumption for the same measurement m(t) are about the same as for "Aerosol 5µm" assumption.
$\frac{D_{F,V}(t)}{D_{F,5\mu m}(t)} = \frac{e_{F,V}}{e_{F,5\mu m}} \cdot \frac{R_{F,5\mu m}(t)}{R_{F,V}(t)}$
days after intake
18.12.2018
3
www.lia.nrw


LIA.nrw
Final step of IDEAS Guidelines for the second monitoring period (25/5 – 13/8)
TECHREC steps starting from routine monitoring (E2)
Monitoring value is 5.47E+4 Bq
TECHREC Step 2 – critical value exceeded
TECHREC Step 3 $I = \frac{M - P}{m(^{1}/_{2})} = \frac{5.47E4\,Bq - 775\,Bq}{0.068} = 7.93E5\,Bq \rightarrow 5.79\,mSv$
$P = 5.39E4\,Bq \cdot m(126d) = 5.39E4\,Bq \cdot 1.44E-2 = 775\,Bq$
TECHREC Step 4 is trivial since e(50) already exceeds 1mSv
TECHREC Step 5 : measurement is not consistent with earlier experience (previous monitoring) -> special monitoring (E3) – step5
18.12.2018
4
www.lia.nrw

LIA.nrw

Special monitoring

- TECHREC E2 Step 5: special monitoring measurement (03.09. and 30.09 with values 3.33E4 Bq and 2.39E4 Bq)
- TECHREC E2 Step 6: annual dose limit potentially exceeded?

$$DIL_{minSM(i)} = \frac{0.02}{e(50)} \cdot 0.3 \cdot m(\Delta T) \cdot \frac{1}{SF_i^2} \qquad SF = \exp(\sqrt{\ln(1.07)^2 + \ln(1.25)^2} = 1.26$$

Measured	m(ΔT)	DIL_minSM(i)
5.47E4 Bq	40d : 6.8E-2	3.52E4 Bq
3.33E4 Bq	60d: 4.7E-2	2.43E4 Bq
2.39E4 Bq	88d: 2.9E-2	1.50E4 Bq

All measurements exceed the derived investigation levels -> dose limit potentially exceeded, proceed to IDEAS stage 4 and stage 5 (pure inhalation)

18.12.2018 5 www.lia.nrw

LIA.nrw

IDEAS Guidelines stage 5

- Since initial dose estimate is >1mSv, proceed to stage 5B (5.7-5.14)
- Time of intake not known-> 5.12
- Assessment of dose by simultaneous fitting of time of intake and absorption type
- Measurements, corrected for previous intake:

Date	Measurement	P
13.08	5.4E74 Bq	775 Bq
02.09	3.33E4 Bq	543 Bq
30.09	2.39E4 Bq	330 Bq

LIA.nrw

IDEAS Guidelines Stage 5 (2)

- Check of goodness of fit using default values (mid-point intake, 5µm) **[5.12.1]**

$$\chi_0^2 = \sum_i \left(\frac{\ln(m_i) - \ln(I \cdot m(t_i))}{\ln(SF_i)} \right)^2 = 2.63E-01$$

$\chi^2(5\%,2) = 5.99$, p-value (chidist(0.263;2)) is 0.88 **Fit can be accepted!**

- Check obtained dose **[5.12.2]**: maximum likelihood estimate using (eq. 14.9) yields I=7.66E5 Bq, with a resulting e(50) of 5.60 mSv
- The dose is less than 6 mSv, therefore **[5.12.3]** is the final step (record dose and parameters).

18.12.2018 7 www.lia.nrw

LIA.nrw

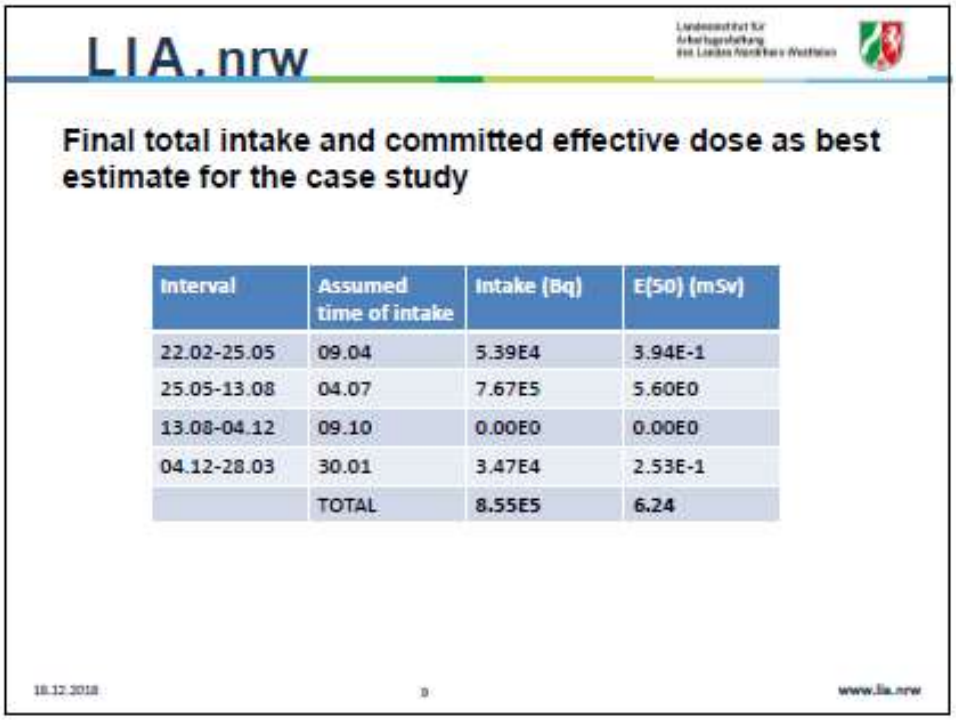
Intake for third monitoring period? (13.08 – 04.12)

- In Step 2, it has to be checked whether the measured value is significant.
- Measurement value: 1.03E4 Bq. Measurement is above the critical value (~200 Bq) for the monitoring period
- Contribution from previous intakes: 105 Bq (1st period) and 6819 Bq (2nd period): Total P=6924 Bq.
- Comparison of measured value with P combined with scattering factor:

$$\frac{P}{SF^2} = \frac{6924}{1.26^2} = 4361 < 10300 < P \cdot SF^2 = 10993$$

- Conclusion: measurement is consistent with previous intakes, no new intake occurred in the 3rd monitoring interval

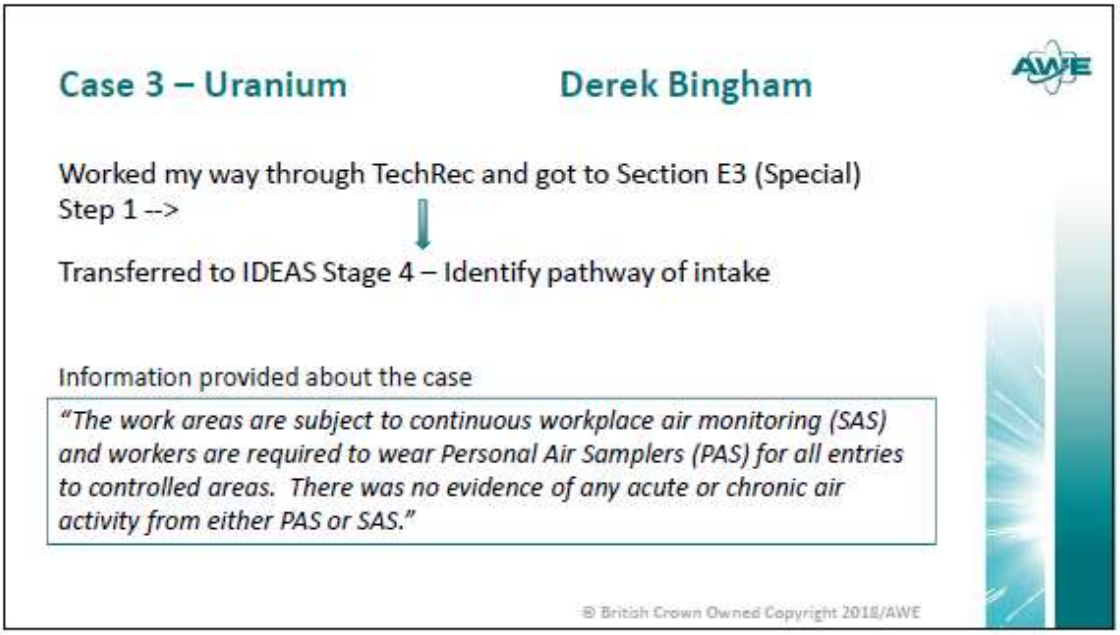
18.12.2018 8 www.lia.nrw

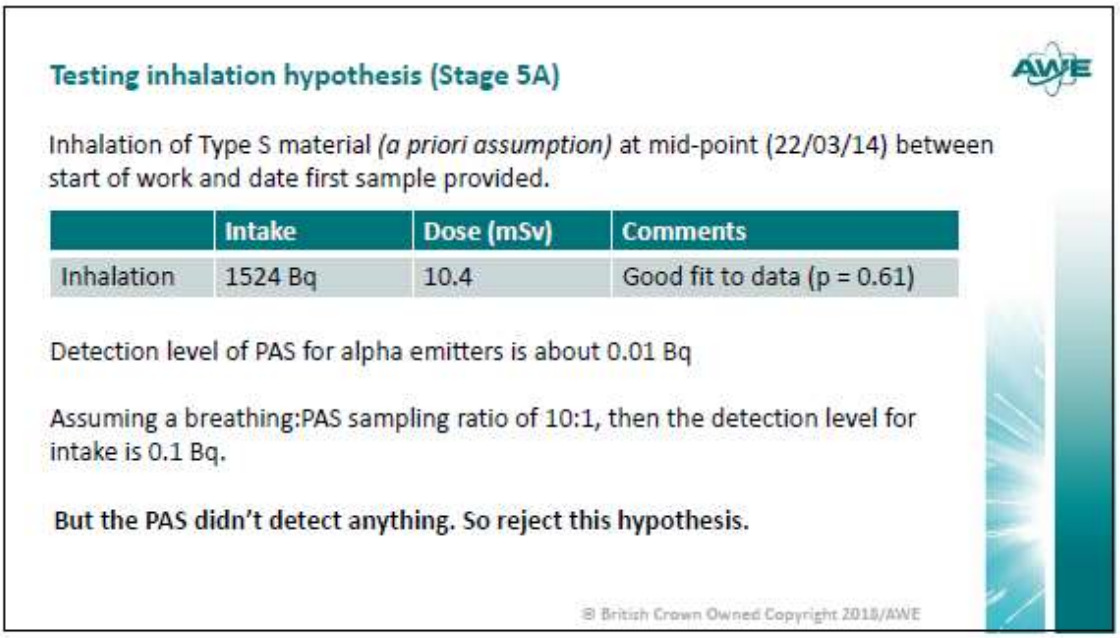

LIA.nrw
Final total intake and committed effective dose as best estimate for the case study
Interval | Assumed time of intake | Intake (Bq) | E(50) (mSv)
22.02-25.05 | 09.04 | 5.39E4 | 3.94E-1
25.05-13.08 | 04.07 | 7.67E5 | 5.60E0
13.08-04.12 | 09.10 | 0.00E0 | 0.00E0
04.12-28.03 | 30.01 | 3.47E4 | 2.53E-1
TOTAL | 8.55E5 | 6.24
18.12.2018
9
www.lia.nrw


LIA.nrw
LIA.nrw
gesünder arbeiten und leben.
Thank you for your attention.
www.lia.nrw

16.3 Presentations related to Case 3

Presentation of Derek Bingham





Testing inhalation and ingestion hypothesis (Stage 7A)

Acute intake (22/03/14) by inhalation of Type S and chronic intake by ingestion (01/02/14 – 10/07/14, f_1 of 0.02 default for unspecified materials).

	Intake	Dose (mSv)	Comments
Inhalation	0.0004 Bq	< 0.001	Good fit to data (p = 0.74)
Ingestion	0.35 Bq/d	0.003	

Not sure why I chose a *chronic* ingestion intake – perhaps to mimic a dietary intake. But this is a plausible scenario.

Testing ingestion hypothesis (Stage 6A)

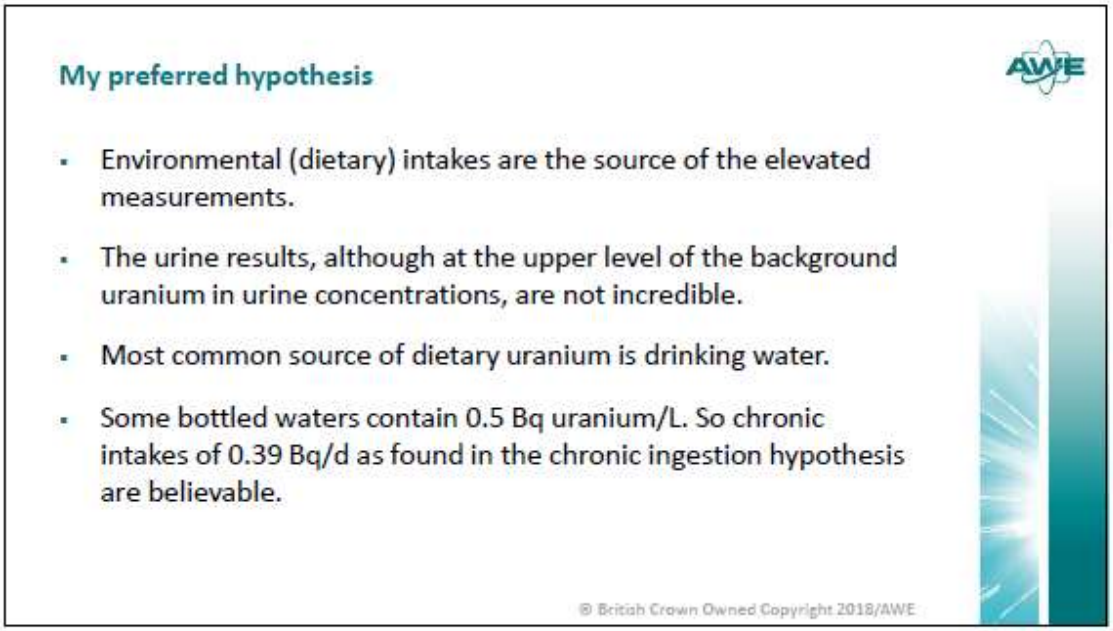
Acute intake (22/03/14) by ingestion of unspecified material (f_1 of 0.02).

	Intake	Dose (mSv)	Comments
Inhalation	787 Bq	0.039	Acceptable fit (p = 0.07)

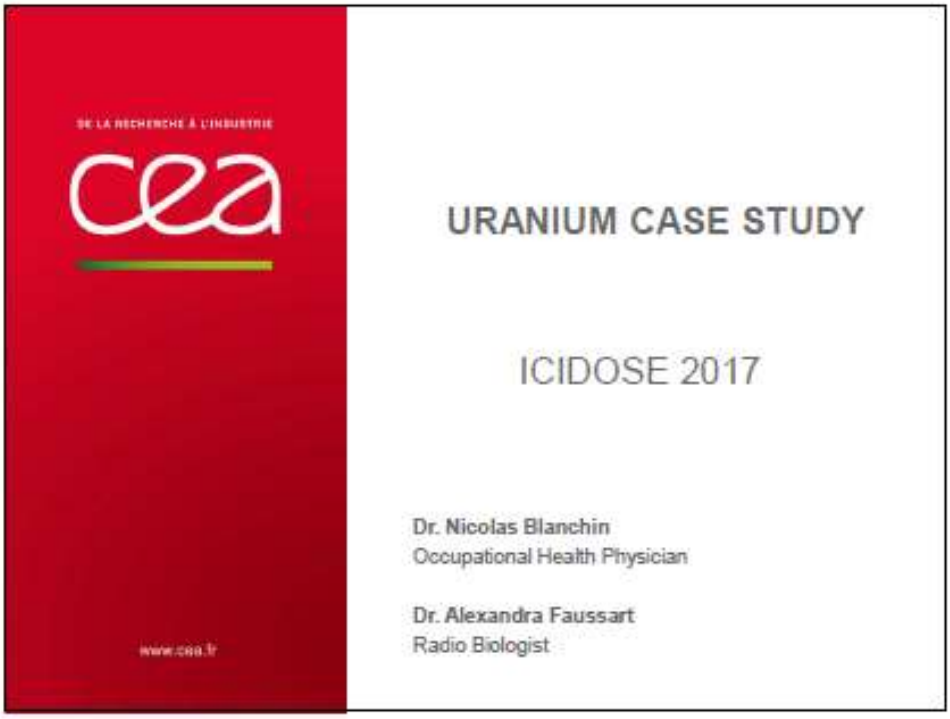
Is an occupational intake by ingestion realistic?

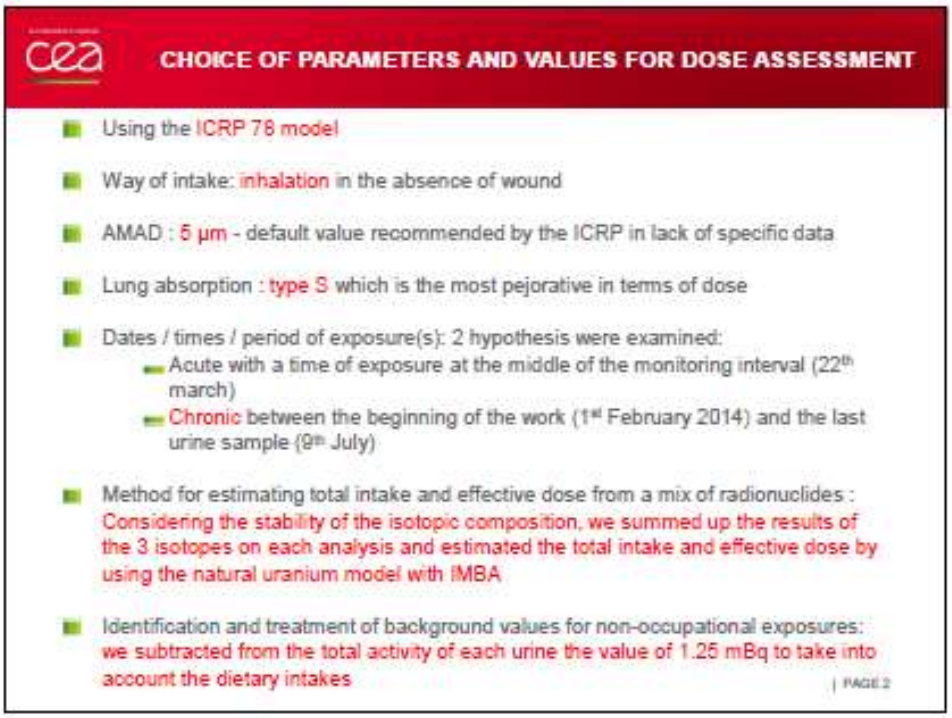
Inadvertent intakes by ingestion might be more common than expected but an intake of this size seems unlikely given the absence of other indicators (e.g. personal contamination).

Accepted this as the assessment. Not enough data to do anything more.


My preferred hypothesis
AWE
Environmental (dietary) intakes are the source of the elevated measurements.
The urine results, although at the upper level of the background uranium in urine concentrations, are not incredible.
Most common source of dietary uranium is drinking water.
Some bottled waters contain 0.5 Bq uranium/L. So chronic intakes of 0.39 Bq/d as found in the chronic ingestion hypothesis are believable.
© British Crown Owned Copyright 2018/AWE

Presentation of Nicolas Blanchin





WHY CHOOSING THE CHRONIC INHALATION AS PATHWAY OF INTAKE ?

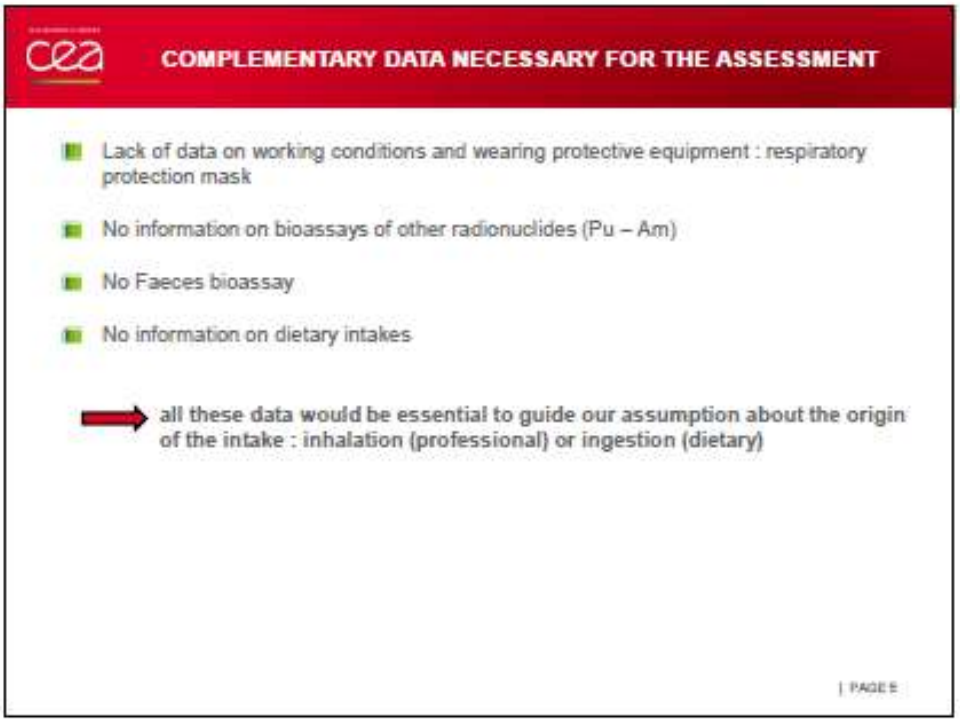
- No evidence of any acute or chronic air activity from either Personal Air Samplers (PAS) or Static Air Samplers (SAS) -> no evidence in favor of inhalation event
- No records of any skin contamination event
- No records of any wounding event
- The results of urine activities are very stable but it could also be compatible with early acute contamination
- But in the hypothesis of an acute contamination, the estimated activity would have been high (about 1000 Bq for an S type and about 50 Bq for an M type) and probably detected by Personal Air Samplers (PAS) or Static Air Samplers (SAS)
- **In the hypothesis of chronic contamination, daily intakes of few Bq could explain the observed results and would be more consistent with the absence of event identified**

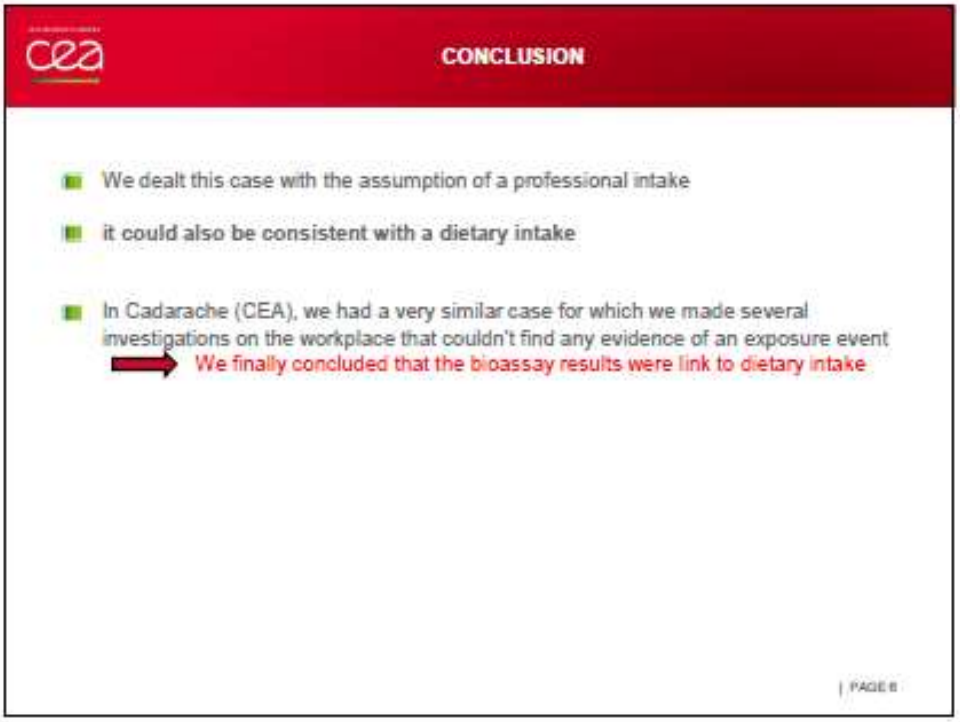
| PAGE 3

ESTIMATION OF THE INTAKE AND COMMITTED EFFECTIVE DOSE

- We did the assessment of the intake and of the committed effective dose by following the TECHREC recommendations (**stage 5C**) and IDEAS guidelines (**step 5.15**)
- Using the default parameter values of the ICRP 78 for inhalation type S
- Using the software IMBA version 4.4.55
- In the assumption of a chronic inhalation :
  - **Total intake = 500 Bq**
  - **Total committed effective dose = 3.20 mSv**

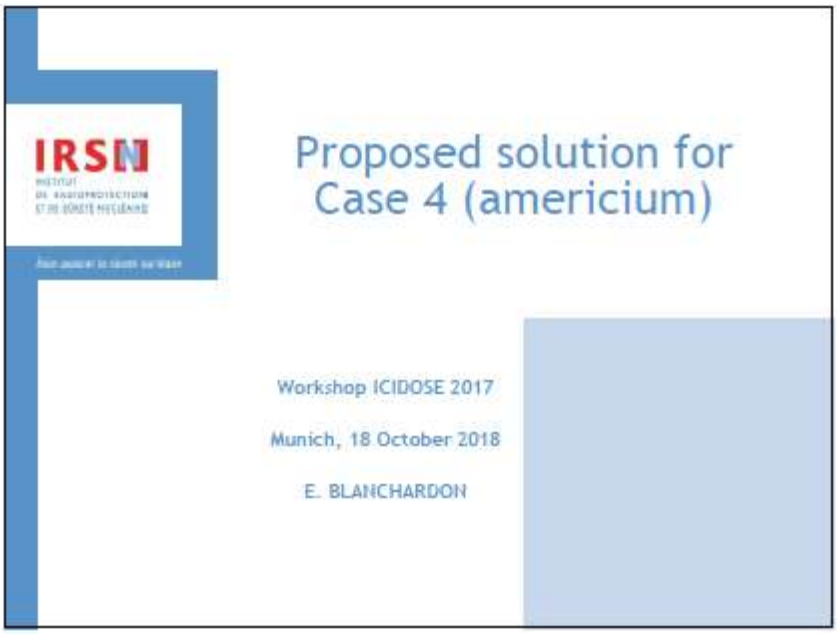
| PAGE 4

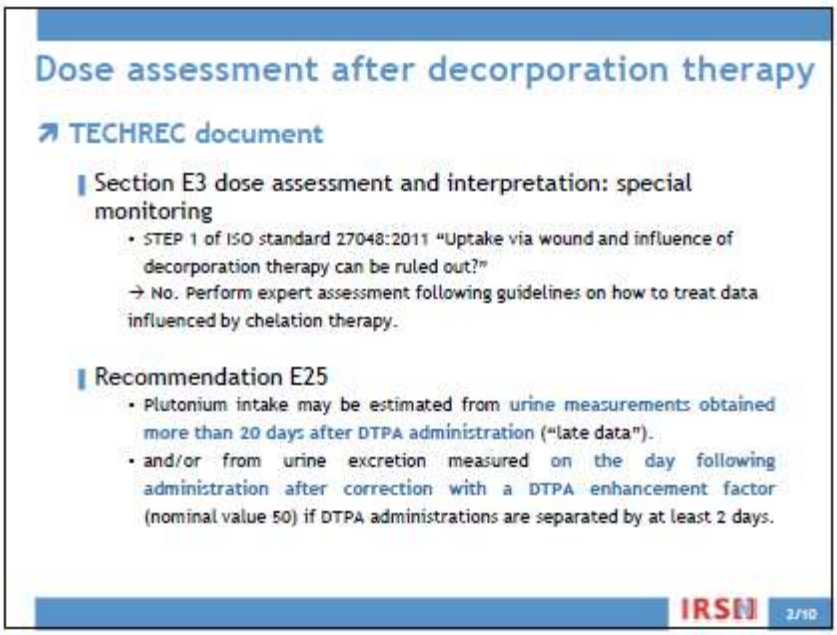

COMPLEMENTARY DATA NECESSARY FOR THE ASSESSMENT
Lack of data on working conditions and wearing protective equipment : respiratory protection mask
No information on bioassays of other radionuclides (Pu – Am)
No Faeces bioassay
No information on dietary intakes
all these data would be essential to guide our assumption about the origin of the intake : inhalation (professional) or ingestion (dietary)
| PAGE 5

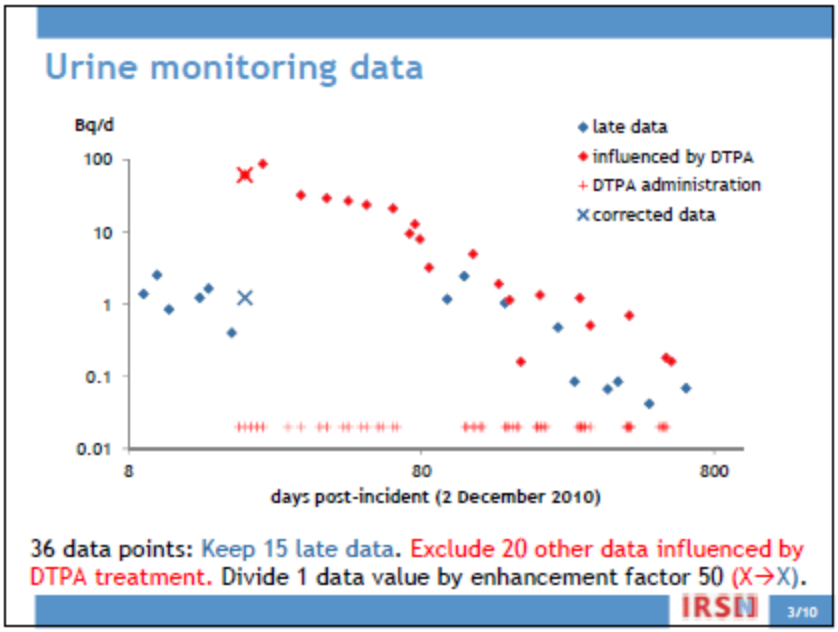

CONCLUSION
We dealt this case with the assumption of a professional intake
it could also be consistent with a dietary intake
In Cadarache (CEA), we had a very similar case for which we made several investigations on the workplace that couldn't find any evidence of an exposure event
We finally concluded that the bioassay results were link to dietary intake
| PAGE 6

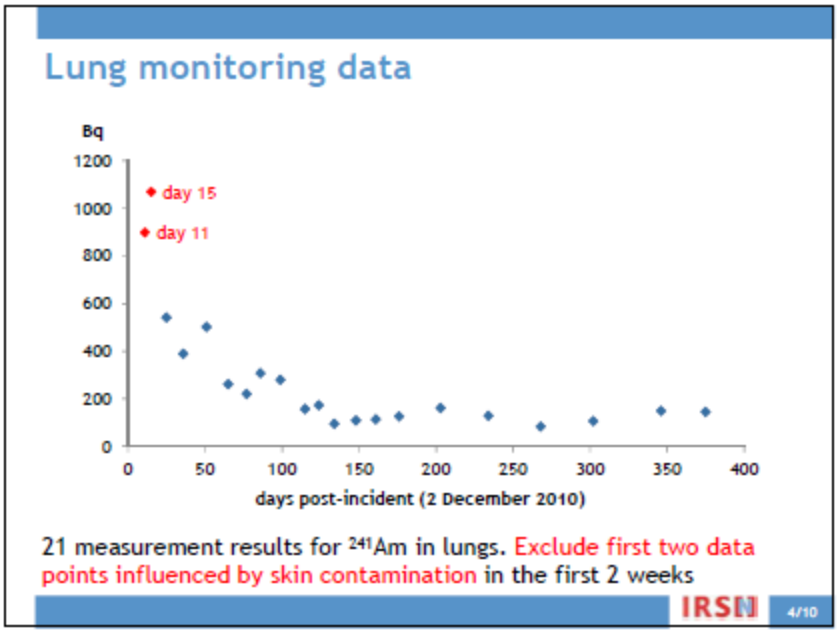
16.4 Presentations related to Case 4

Presentation of Eric Blanchardon






Urine monitoring data
Bq/d
100
10
1
0.1
0.01
late data
influenced by DTPA
DTPA administration
corrected data
8
80
800
days post-incident (2 December 2010)
36 data points: Keep 15 late data. Exclude 20 other data influenced by DTPA treatment. Divide 1 data value by enhancement factor 50 (X→X).
IRSN
3/10


Lung monitoring data
Bq
1200
1000
800
600
400
200
0
day 15
day 11
0
50
100
150
200
250
300
350
400
days post-incident (2 December 2010)
21 measurement results for 241Am in lungs. Exclude first two data points influenced by skin contamination in the first 2 weeks
IRSN
4/10

Measurement uncertainty

- TECHREC recommendation F02
  - Scattering factors (SF) from IDEAS Guidelines for Type B uncertainty

Type of measurement	Scattering factor, *SF*		
In vivo	Type A	Type B	Total
intermediate photon energy (20-100 keV)	1.3	1.25	1.4
Urine (type B uncertainty)			
simulated 24-hour sample (normalised activity)		1.6 (1.3-1.8)	

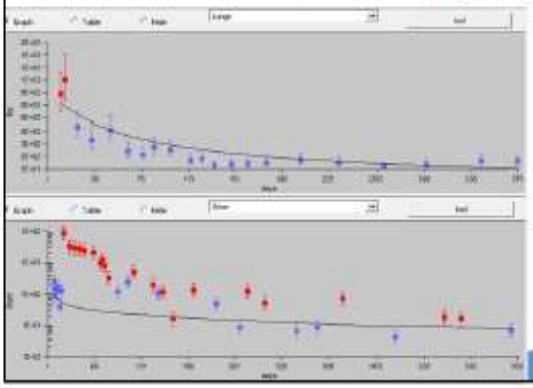
- Type A uncertainty provided by laboratory: $SF_A = e^{\left(\frac{\sigma_M}{M}\right)}$
  - $\frac{\sigma_M}{M}$ =10 % for urine, $\frac{\sigma_M}{M}$ = 10-35% for lung.
  - SF_A (urine) = 1.11, SF_A (lung) = [1.16 - 1.42]
- Overall uncertainty: $SF = e^{\sqrt{(\ln(SF_A))^2+(\ln(SF_B))^2}}$
- SF (urine) = 1.62 SF (lung) = [1.31 - 1.5]

IRSN 5/10

Fitting model to data

- Simple evaluation (IDEAS Guidelines stage 5A) with IMBA software
  - Inhalation intake on 2 December 2010 (day 0) with default absorption Type M,
  - Default transfer rates for HRTM (ICRP 66), GITM (ICRP 30), americium biokinetic model (ICRP 67), AMAD = 5 µm, f_1 = 5 x10^{-4}

  →Committed effective dose = 441 mSv (high dose !)



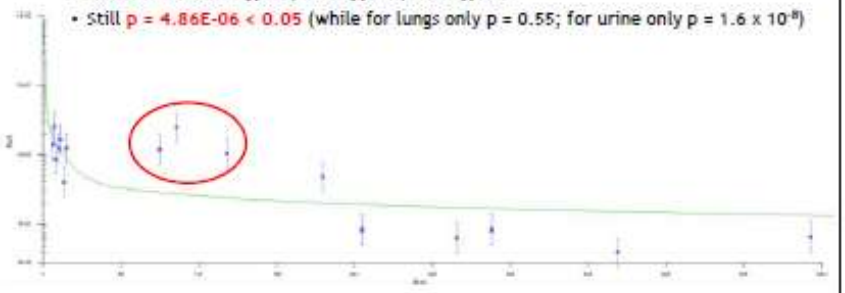
- Bad fit with Type M
  p = 5.8 x 10^{-10}
- Worse with Type S
  p = 6.2 x 10^{-246}
- Zero with Type F
  p = 0.0

IRSN 6/10

Fitting model to data

Special evaluation (IDEAS Guidelines stage 5B) with IMBA software

- step 5.13 : fitting a mixture of default absorption types (F,M,S)
- Best fit with 30% Type F, 58% Type M, 12% Type S
- Still p = 4.86E-06 < 0.05 (while for lungs only p = 0.55; for urine only p = 1.6 x 10^{-8})



- The 3 data of 10 March, 24 March and 5 May 2011 are from urine samples collected 32, 46 and 25 d after DTPA administration. They could still be influenced by DTPA and bias the assessment. Are they outliers? This question could have been raised already in the identification and preparation of measurement data (IDEAS stage 5A-step 5.1)

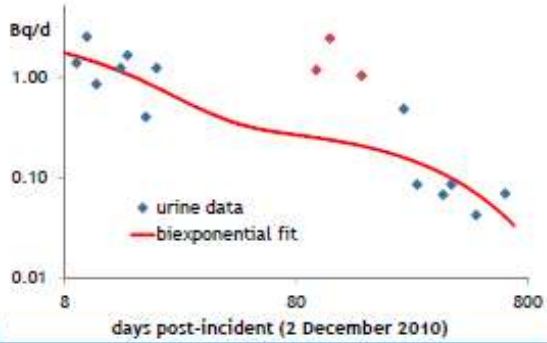
IRSN 7/10

Fitting model to data

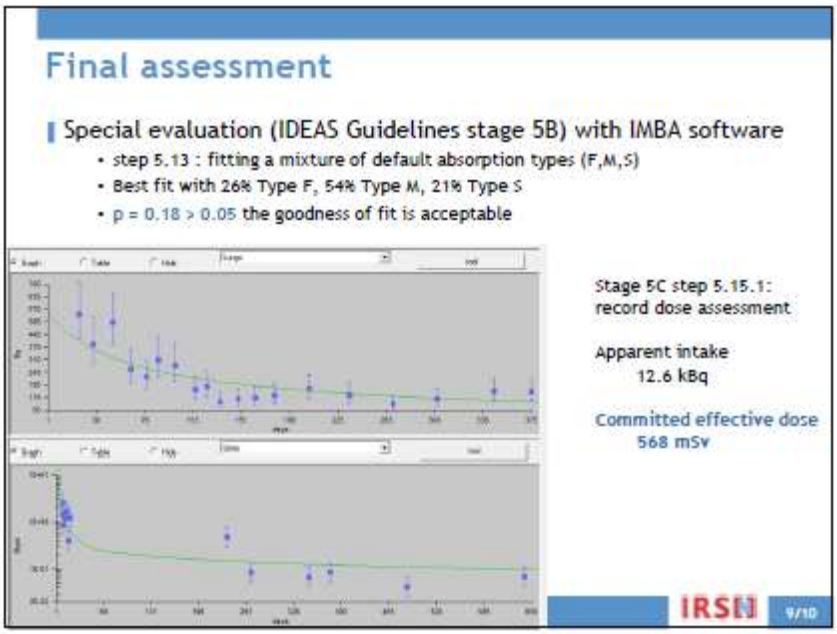
Identification of rogue data (IDEAS Guidelines section 6.1)

- Fitting $f(t) = 2.95e^{-0.0020 \cdot t} + 0.346e^{-0.00334 \cdot t}$ to (blue) urine data with Excel solver
- Confirmation of lognormal dispersion with autocorrelation test statistics
- Distance of the suspected (red) outliers from the trend of the other data is M/f(t) = 4.7, 10.3 and 5.0 respectively, all > SF^3 = 4.2

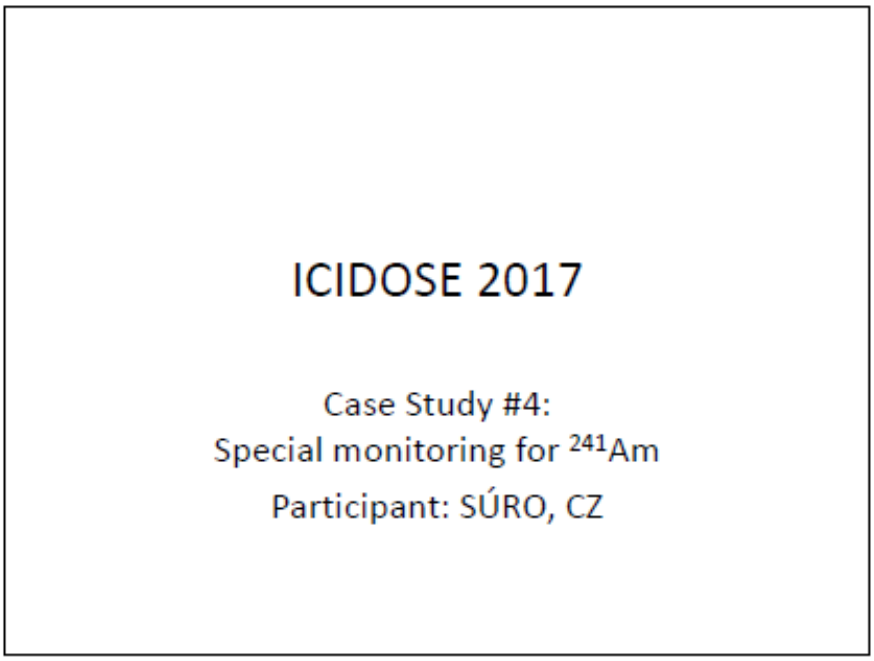
→The 3 data are excluded from further assessment.

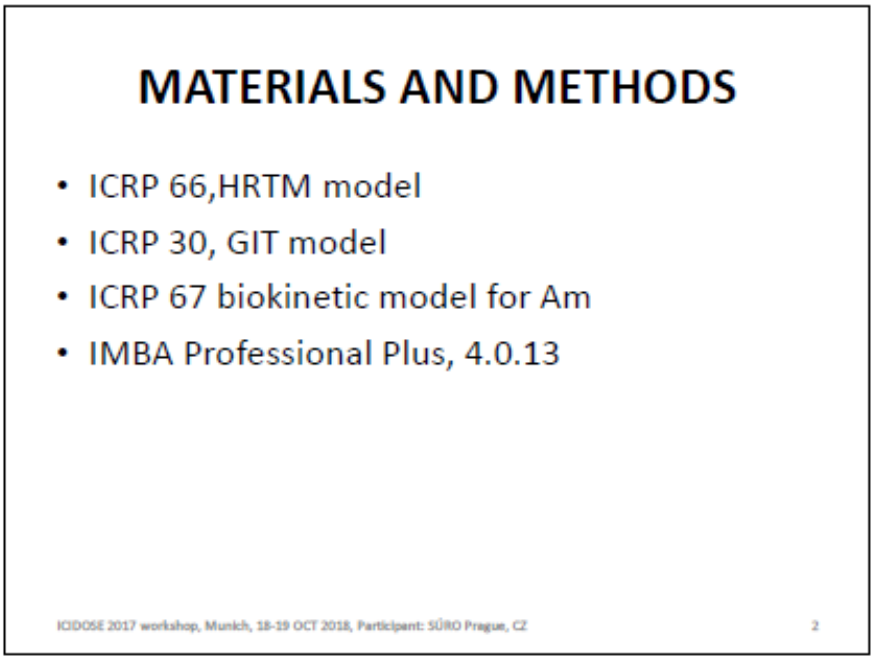


IRSN 8/10


Final assessment
Special evaluation (IDEAS Guidelines stage 5B) with IMBA software
• step 5.13 : fitting a mixture of default absorption types (F,M,S)
• Best fit with 26% Type F, 54% Type M, 21% Type S
• p = 0.18 > 0.05 the goodness of fit is acceptable
Stage 5C step 5.15.1:
record dose assessment
Apparent intake
12.6 kBq
Committed effective dose
568 mSv
IRSN
9/10

Presentation of Pavel Fojtík



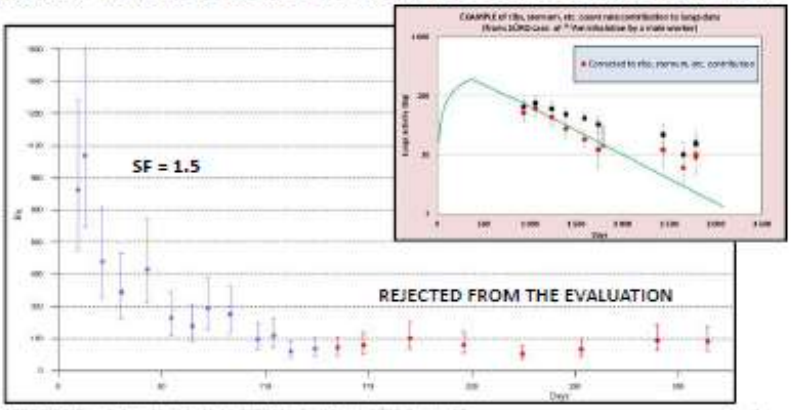


CASE EVALUATION (Stage 5)

Steps 1 to 4: Skipped as „obvious" (based on measurements and case data)

Step 5.1: Preparation and selection of data (lungs data)

Lung data: Restricted to the first 13 data only (due to ribs & sternum contribution)



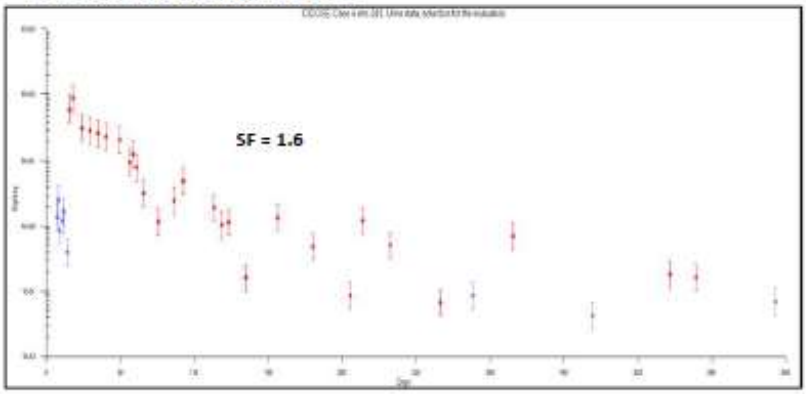
ICIDOSE 2017 workshop, Munich, 18-19 OCT 2018, Participant: SÚRO Prague, CZ 3

CASE EVALUATION (Stage 5 continued)

Step 5.1: Preparation and selection of data (continued)

Urine data: Only data measured 3 weeks after the last DTPA treatment selected.

ICRP biokinetic and dosimetric models can be applied to calculate the apparent intake and subsequently the dose.



ICIDOSE 2017 workshop, Munich, 18-19 OCT 2018, Participant: SÚRO Prague, CZ 4

CASE EVALUATION (Stage 5 continued)

Steps 5.2 to 5.5: Skipped based on case data and Stage 5B/Step 5.7 is triggered

Stage 5B

Step 5.7:

Step 5.7.1. Data sufficiency check.

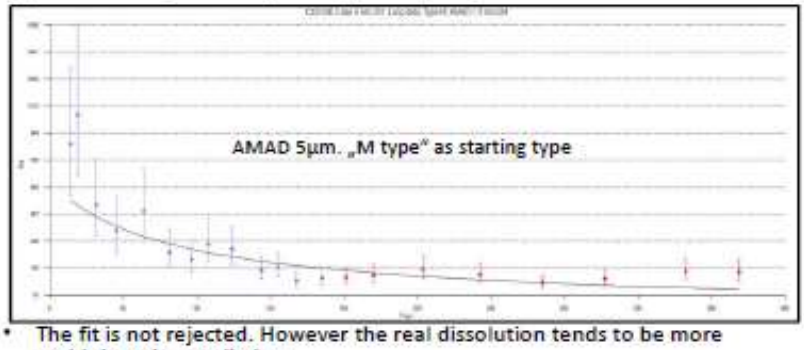
Only two types of data are available.

Data are insufficient, therefore the result should be treated with caution.

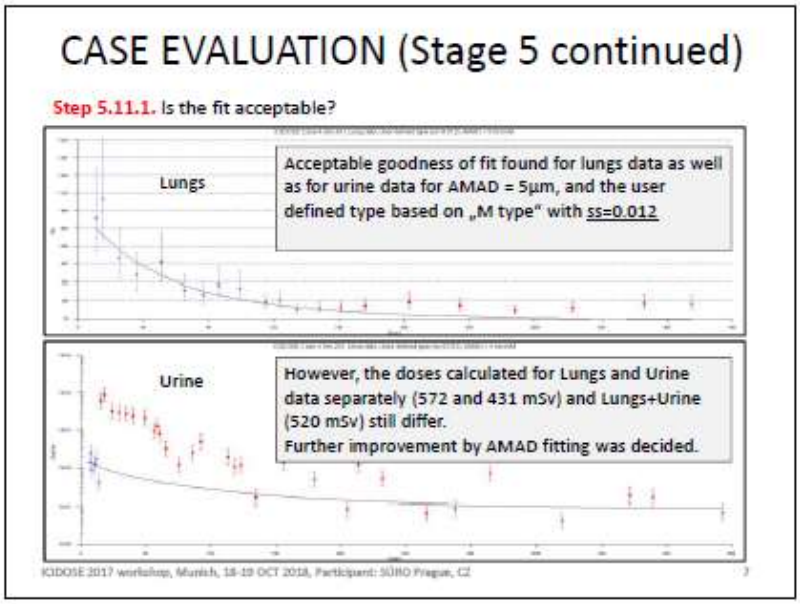
- Step 5.8. Skipped; time of intake is known
- Step 5.9. and 5.10. Skipped as no early faeces and lung data are available.
- Therefore *a priori* AMAD of 5 µm will be used as a starting value for a fitting the best AMAD as an *a posteriori* AMAD.
- The motivation for changing AMAD is the fact that a protection mask was used. Therefore only very small particles (AMAD ~ 0.2 µm) might have penetrated.

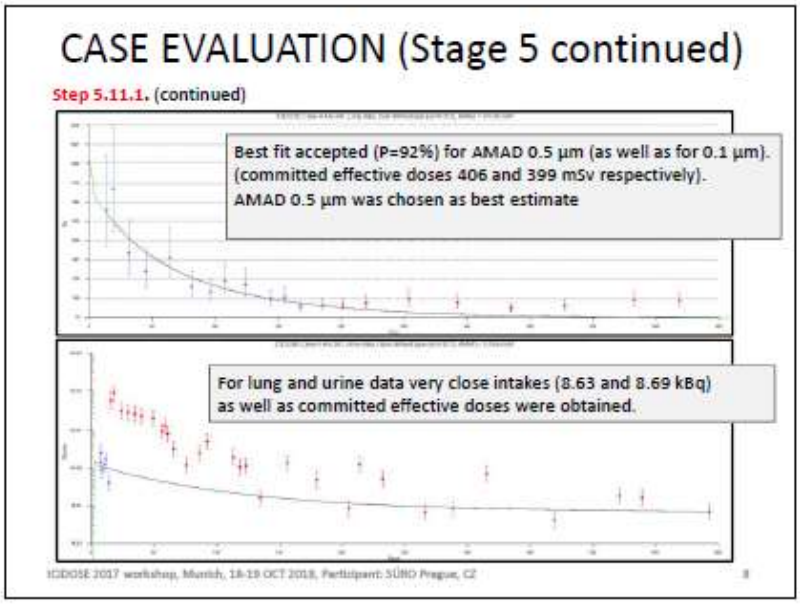
CASE EVALUATION (Stage 5 continued)

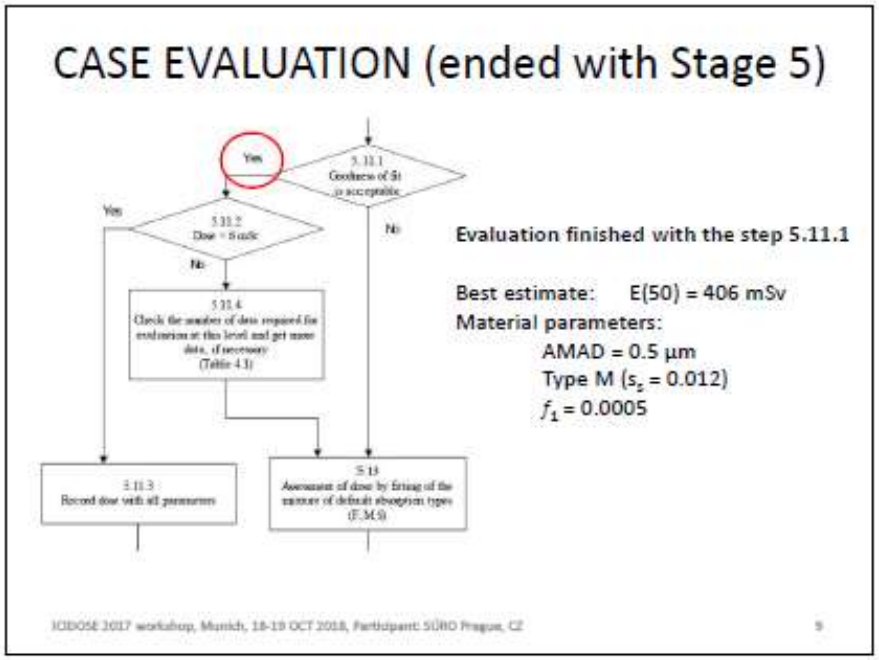
Step 5.11. Fitting the absorption type. Only lungs data used.



- The fit is not rejected. However the real dissolution tends to be more rapid than the prediction.
- Also, the doses calculated from lung only, urine only, and lung+urine differ almost by a factor of 2.
- It was decided that only the parameter for the fraction dissolved slowly will be changed and fitted.


CASE EVALUATION (Stage 5 continued)
Step 5.11.1. Is the fit acceptable?
Lungs
Acceptable goodness of fit found for lungs data as well as for urine data for AMAD = 5µm, and the user defined type based on „M type" with ss=0.012
Urine
However, the doses calculated for Lungs and Urine data separately (572 and 431 mSv) and Lungs+Urine (520 mSv) still differ.
Further improvement by AMAD fitting was decided.


CASE EVALUATION (Stage 5 continued)
Step 5.11.1. (continued)
Best fit accepted (P=92%) for AMAD 0.5 µm (as well as for 0.1 µm).
(committed effective doses 406 and 399 mSv respectively).
AMAD 0.5 µm was chosen as best estimate
For lung and urine data very close intakes (8.63 and 8.69 kBq)
as well as committed effective doses were obtained.


CASE EVALUATION (ended with Stage 5)
Yes
5.11.1
Goodness of fit
is acceptable
No
Yes
5.11.2
Dose > 0 mSv
No
5.11.4
Check the number of data required for
evaluation at this level and get more
data, if necessary
(Table 4.1)
5.11.3
Record dose with all parameters
5.13
Assessment of dose by fitting of the
mixture of default absorption types
(F,M,S)
Evaluation finished with the step 5.11.1
Best estimate: E(50) = 406 mSv
Material parameters:
AMAD = 0.5 µm
Type M (s_s = 0.012)
f_1 = 0.0005
IODOSE 2017 workshop, Munich, 18-19 OCT 2018, Participant: SÚRO Prague, CZ
9