

Coordination of Research on Internal Dosimetry in Europe: the CONRAD Project

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Short Title: The CONRAD Project

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ABSTRACT

The European Radiation Dosimetry Group, EURADOS, initiated in 2005 the CONRAD Project, a Coordinated Network for Radiation Dosimetry funded by the European Commission (EC), within the 6th Framework Programme (FP). The main purpose of CONRAD is to generate a European Network in the field of Radiation Dosimetry, to promote both research activities and dissemination of knowledge. The objective of CONRAD Work Package 5 (WP5) is the coordination of research on assessment and evaluation of internal exposures. Nineteen institutes from 14 countries participate in this action. Some of the activities to be developed are continuations of former European projects supported by the EC in the 5th FP (OMINEX and IDEAS). Other tasks are linked with ICRP activities, and there are new actions never considered before. A collaboration is established with CONRAD Work Package 4, dealing with Computational Dosimetry, to organise an intercomparison on Monte Carlo modelling for *in vivo* measurements of ^{241}Am deposited in a knee phantom. Preliminary results associated with CONRAD WP5 tasks are presented here.

INTRODUCTION

The Coordination Action CONRAD (Coordinated Network for Radiation Dosimetry), supported by the EC (6th FP) for research and training in nuclear energy (Contract No FI6R-012684), was initiated in January 2005. The partners of the project are EURADOS (EUropean RADIation DOSimetry Group), TU Delft (The Netherlands) and University of St. Gallen (Switzerland). The objectives of this action are the analysis of the options for sustainable networks linking research actors and end users, and to coordinate research into measurements and calculations for radiation protection at workplaces. To achieve the stated objectives seven work packages (WP) are carried out.

The aim of CONRAD Work Package 5 (WP5) is the coordination of research and the dissemination of knowledge in the field of internal dosimetry. The research to be coordinated will improve the reliability in the assessment of internal doses. Thirty two scientists (15 full CONRAD members, 17 corresponding members) from 18 institutes and 11 countries participate in this working group; CIEMAT (Spain) is the institution chairing this action. The tasks to be developed include a study of uncertainties associated with the assessment of doses after intake of radionuclides and the refinement of the IDEAS¹ general guidelines for internal dose evaluation after first application by internal dosimetry services. The impact of the use of new biokinetic models for dose assessment is to be evaluated, focusing initially on the new ICRP Human Alimentary Tract Model (HATM). New developments in the generation of voxel phantoms and Monte Carlo simulations for assessment of intakes from *in vivo* measurements are also to be considered. An Emergency Network is planned to be established, to coordinate procedures and methodologies to be applied for the interpretation of monitoring data for emergency workers after accidental or deliberate releases of radionuclides (e.g. nuclear terrorism). Finally, WP5 has been working on the maintenance of the existing IDEAS bibliographic, internal contamination and case evaluation databases². The EURADOS/CONRAD WP5 web site (www.eurados.org) summarises the objectives and activities proposed in this action, and includes the links of ENEA/Ideas and SCK/Ideas web pages.

Assessment of internal exposures: Uncertainty studies and refinement of IDEAS Guidelines

This Task of CONRAD WP5 is coordinated by HPA (UK) and ENEA (Italy) and has as main objective to improve the assessment of realistic uncertainties associated with the evaluation of the intake and the dose, focusing on the application of the IDEAS Guidelines. Software has been developed at HPA, IRSN, RPI Kiev and IBPh Moscow to enable uncertainty analyses

using Monte Carlo simulations. Probability distributions are assigned to those parameters that most affect the assessed dose and possible correlations between parameter values are considered. One of the software codes being developed estimates the probability distribution of an individual's dose *conditional* on *observed* monitoring data³. In this case, Bayesian inference methods are used to estimate the uncertainty on the estimated dose.

Generally, a lognormal distribution with a given geometric standard deviation is used to describe the distribution of measurements performed to evaluate internal exposures. Furthermore, according to IDEAS Guidelines the overall uncertainty of an individual monitoring value can also be described in terms of a lognormal distribution and the scattering factor (SF) is defined as the geometric standard deviation; this approach is valid when Type A uncertainty (counting statistic) is small (<30%). A procedure was developed⁴ to evaluate, mathematically, SF values for different radionuclides and types of monitoring data using real data contained in the IDEAS Internal Contamination Database². Preliminary results show that the SF values are broadly in agreement with the values suggested in the IDEAS Guidelines, which were based mainly on expert judgement. However, the SF values for faecal excretion (1.9 to 3.5) are at the lower end of the range (2 to 5) suggested in the IDEAS Guidelines⁴.

To promote the dissemination of knowledge among the internal dosimetry community, a page inside the ENEA Bologna centre web page has been set up (www.bologna.enea.it/attivita/ideas.html/). This site has the aim of promoting the continuation of the activities of IDEAS inside the CONRAD project and will be upgraded as a working tool to meet the needs of the project. For the time being, it is possible to download from this page the three IDEAS databases via the SCK•CEN IDEAS web page (www.sckcen.be/ideas/), the ENEA report on IDEAS WP3, the final report of the IDEAS/IAEA intercomparison exercise and the final version of guidelines as a pdf file (Report FZKA 7243). The following links are also available: the IMIE software web page, ICRP's INDOS public access web page (to download the draft of the ICRP Guidance Document) and the CONRAD WP5 page on the EURADOS web site.

Research Studies on Biokinetic Models

The research activity of this WP5 task is coordinated by BfS (Germany). The impact of the application of new models for occupational dose assessment is to be evaluated, focusing initially on the new Human Alimentary Tract Model (HATM)⁵. Age-dependent doses to members of the public are beyond the scope of this task. Results of this group are important as

a support for on-going efforts of the ICRP Committee 2 Task Group on Dose Calculation (DOCAL).

The new ICRP human alimentary tract model (HATM) has been implemented into 6 computational codes by 6 European Institutes (HPA, IRSN, RPI Kiev, BfS, Univ. of Milan and ENEA). As a first step, an intercomparison has been carried out of biokinetic results (ie. number of disintegrations within HATM compartments, and faecal excretion rates) for a simplified model (direct absorption from the small intestine, without any retention and recycling in the wall). Calculations have been made for 11 radionuclides (^{133}Te , ^{18}F , $^{99\text{m}}\text{Tc}$, ^{127}Te , ^{123}I , ^{111}In , ^{201}Tl , ^{141}Ce , ^{60}Co , ^{129}I , ^{238}U) with different half-lives and different f_A absorption values. The results for the number of disintegrations within the compartments of the alimentary tract confirmed a very good agreement and the comparison of faecal excretion rates showed some preliminary discrepancies which were solved; thus all computational results agree in this initial phase of the work.

An important contribution of this working subgroup was the study of the absorption formulation of the new HAT model; the ICRP text has been revised after some inconsistencies were identified by CONRAD partners.

The study has continued with more complicated cases, applying the adult male parameters for total diet without systemic contributions by secretion into the HATM. Three new work topics have been initiated. Firstly, calculations have been made of the number of nuclear transformations of parent and daughter radionuclides within the HATM compartments for two cases: $^{90}\text{Sr}/^{90}\text{Y}$ and ^{234}Pu with its progeny ^{234}Np , ^{230}U and ^{226}Th . Secondly, the absorption from different sites of the alimentary tract for intakes of ^{131}I has been studied, with the assumptions that half of the iodine contained in the stomach is absorbed directly to the blood, and that 0.98 of the iodine in the small intestine is absorbed directly to the blood. Thirdly, recycling in the SI wall of the alimentary tract has been studied, with calculations performed of the nuclear transformations for ^{59}Fe .

With reference to the ICRP human respiratory tract model (HRTM), no specific work has been planned so far. Some calculation could be carried out in cooperation with the ICRP DOCAL group, to assess the effect of changing default absorption parameters or considering the bound state compartments for specific elements.

At the moment no work with new systemic models is planned, at least until the final version of new ICRP systemic models are published. IRSN has proposed a study for the development of a model describing the effect of administration of DTPA. The NCRP wound model is not

available so far, but the CONRAD biokinetic group will be involved in this matter as soon as the structure and default parameters of the model are available.

Monte Carlo Applications for In Vivo Assessment of Intakes

New developments in the use of voxel phantoms and Monte Carlo (MC) applications for the assessment of intakes from in vivo measurements have been evaluated. Innovative approaches have been generated for the creation and application of voxel phantoms used for MC calculations of calibration factors for whole body counting systems. The objective of this Task-group coordinated by IRSN (France) is to extend such investigations to the improvement in the reconstruction of numerical anthropomorphic phantoms, taking advantage of recent progress in image-processing codes. Specific applications for in vivo monitoring have been studied and a collaboration with CONRAD Work Package 4 (WP4) "Computational Dosimetry" is established in order to coordinate common areas of work in this field.

This Task is planned to be developed by carrying out an "Intercomparison on Monte Carlo (MC) modelling for in vivo measurements of Americium in a knee phantom"⁶. IRSN, CIEMAT and ENEA are involved in the organisation of the exercise. The final goals are the comparison of MC codes and the capability of laboratories to deal with such kind of exercises. A questionnaire titled: "Expression of interest in taking part in experimental-numerical intercomparison on in vivo measurements" was elaborated and sent to potential participants. Up to now, 15 laboratories express its interest answering the questionnaire; 10 of them are able to create numerical phantoms from CT or MR images and for 6 participants a segmentation tool is available.

A CT scan of a plastic anthropometric knee phantom was made by CIEMAT; the production of two sets of raw data was performed (non-segmented and segmented). The files were distributed to the participants to be implemented in their own MC codes. Technical information concerning the LE Ge detectors was provided; the modelling of the counting geometry, with 2-detectors located over the knee voxel phantom will be required. Final calculations to complete the exercise are needed to obtain the counting efficiency and the full ²⁴¹Am spectrum.

As a complementary activity to the Monte Carlo modelling for in-vivo determination of Americium in a knee voxel phantom, measurements of the Spitz anthropometric knee phantom (fabricated by Univ. of Cincinnati for calibration purposes) have been performed at CIEMAT and IRSN whole body counting facilities for an in-vivo intercomparison study.

Both laboratories are involved in counting efficiency calculations and in the generation of respective voxel phantoms obtained from CT images of the Spitz phantom obtained in two different hospitals.

A second intercomparison for MC modelling of in vivo measurements of Actinides deposited in the lungs of a torso voxel phantom is planned to be prepared at the end of CONRAD Project, coordinated by IRSN.

Interpretation of monitoring data for emergency workers after accidental or deliberate releases of radionuclides (eg nuclear terrorism)

The objective of this CONRAD WP5 task coordinated by HPA (UK) and STUK (Finland) is the development of a network of people and organisations with responsibilities for emergency monitoring of emergency services personnel and members of the public, and for assessment of doses resulting from internal and external contamination.

The network has been given the acronym EUREMON (EUROpean Emergency MONitoring Network). Its aims are to share information on current strategies and methodologies, and on relevant research and development (R&D) projects. Information collected will be used to define needs for research, advice and training. Individuals who might wish to participate in this network were selected using a number of criteria, including: participation in earlier EU projects relating to monitoring; and/or participation in Work Package 5 of CONRAD; and/or participation in EURADOS work programme, including the EURADOS harmonisation network; and/or a known record of work in this area. The selected individuals were formally invited to join the network, and as of 25/9/06, nineteen positive replies and three negative replies had been received, while replies were awaited for forty invitations. Positive replies had been received from thirteen out of twenty-five EU countries, and from four non-EU countries.

A draft questionnaire has been generated that will collect the information required by both Task 5.4 and the TMT Handbook project (see below). Topics covered include available equipment for internal/external contamination monitoring after accidental or deliberate releases, current dose assessment methodologies, currently-available dose assessment software and relevant emergency exercises. This questionnaire will be distributed to members of the network as soon as network membership is finalised.

A collaboration has been established with other European projects involved in response to radiation emergencies, including TIARA (Treatment Initiatives After Radiological Accidents) and TMT HANDBOOK, which aims to develop a responder's handbook for the triage, monitoring and treatment of members of the public in the event of the malevolent use of

radiation. Some members of the CONRAD Emergency task group are contributing to both projects.

Internal Contamination Databases

The IDEAS Internal Contamination Database is a compilation of published internal contamination cases and represents a very valuable tool for the internal dosimetry community. To ensure that the IDEAS guidelines are applicable to a wide range of practical situations, a database was compiled of cases of internal contamination, which include monitoring data suitable for assessment. A Bibliographic Database was also set up with references to papers in the open literature dealing with problems related to cases of internal contamination. The "Evaluation of Cases Database" contains a summary of information about the evaluations. As the CONRAD project proceeds, the first two databases will be updated with new input; SCK-CEN, HPA, AEKI and ENEA are involved in this action. All three IDEAS databases are made available to the internal dosimetry community by setting them for download on a webpage named IDEAS Databases hosted at the SCK•CEN website. This goal fits very well with one of the more important aims of this European Coordinated Action: "dissemination of knowledge".

CONCLUSIONS

CONRAD Work Package (WP5) coordinates research in the area of internal dosimetry. One of the achievements of this action is the organisation of the first intercomparison on Monte Carlo modelling for in-vivo measurement of ^{241}Am in a knee voxel phantom; this exercise has been prepared in connection with CONRAD WP4. Further achievements are connected with the application of the new ICRP Human Alimentary Tract Model (HATM) with subsequent QA calculations using different codes. A page inside the ENEA Bologna centre web site has been set up, to permit to continue the activities of IDEAS group within the CONRAD Project. SF values have been evaluated for different radionuclides and types of monitoring data using real data contained in the IDEAS Internal Contamination Database. In addition software is currently being developed to estimate uncertainty on the assessed dose from monitoring data. A questionnaire was generated to collect information from persons in charge of the individual monitoring programmes that would be brought into operation after accidental or deliberate releases of radionuclides; a European Emergency Network for Individual Monitoring (EUREMON) is in the process of being established. IDEAS databases are

available at the SCK•CEN and ENEA web pages; now the CONRAD group is looking for new cases.

REFERENCES

1. Project IDEAS. Guidance on internal dose assessments from monitoring data. EU research project under 5th Framework Programme, Contract No. FIKR-CT2001-00160; 2003. Available at <http://www.bologna.enea.it/attivita/ideas.html> (accessed at 6 July 2006).
2. Hurtgen C., Andradi A., Bailey M. R., Blanchardon E., Berkovski, V., Castellani C-M., Doerfel H., Jourdain J-R., LeGuen B., Malatova I., Marsh J. W. and Puncher, M. IDEAS internal contamination database: a compilation of published internal contamination cases. A tool for the internal dosimetry community. *Radiat. Prot. Dosim.* (in press). Database available at: <http://www.sckcen.be/ideas/>. Accessed 27 April 2006. IDEAS data base.
3. Puncher M., Birchall A. Estimating uncertainty on internal dose assessments. Presented at the Workshop of internal dosimetry of radionuclide, occupational, public and medical exposure. Montpellier, France, October 2006.
4. J. W. Marsh, A. Andradi, M.R. Bailey, V. Berkovski, A. Birchall, E. Blanchardon Y. Bonchug), C.M. Castellani, A. D. Desai, H. Doerfel, M-D Dorrian, C. Hurtgen, V. Koukoulidou, M. A. Lopez, A. Luciani, I. Malatova, A. Molokanov, M. Puncher, H. Ratia. Evaluation of scattering factor values for the internal dose assessment following IDEAS guidelines: preliminary results. Presented at the Workshop of internal dosimetry of radionuclide, occupational, public and medical exposure. Montpellier, France, October 2006.
5. D. Noßke, V. Berkovski, A. Birchall, E. Blanchardon, M.C. Cantone, K. Davis, A. Giussani, A. Luciani, J. Marsh, U. Oeh, H. Ratia and M.A. Lopez. The Work of the CONRAD Task Group 5.2 "Research Studies on Biokinetic Models". Presented at the Workshop of internal dosimetry of radionuclide, occupational, public and medical exposure. Montpellier, France, October 2006.
6. J.M. Gómez-Ros, L. de Carlan, D. Franck, G. Gualdrini, M. Lis, M.A. López, M. Moraleda and M. Zankl. Monte Carlo modelling for in vivo measurements of Americium in a knee voxel phantom: general criteria for an international intercomparison. Presented at the Workshop of internal dosimetry of radionuclide, occupational, public and medical exposure. Montpellier, France, October 2006.

Figure 1.- The new ICRP Human Alimentary Tract Model (HATM)

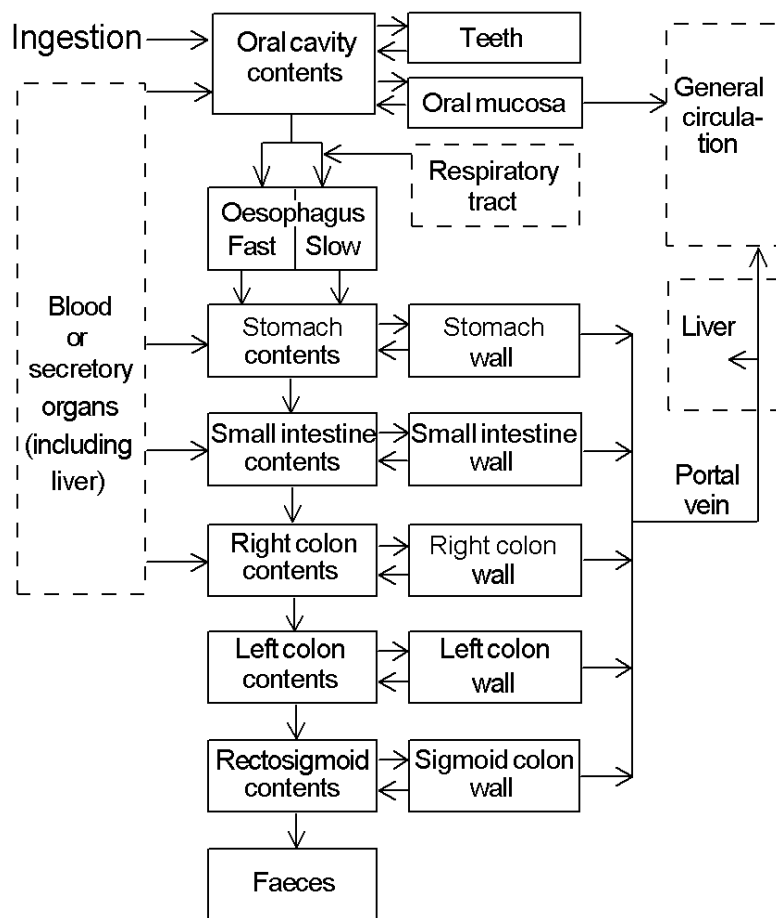


Figure 2.- Joint collaboration between Work Package 4 "Computational Dosimetry" and Work Package 5 "Internal Dosimetry" within the Coordinated Action "CONRAD"

