International Conference on Occupational Radiation Protection

IAEA, Vienna (Austria). December 1-5, 2014

GOBIERNO DE ESPAÑA
MINISTERIO DE ECONOMÍA Y COMPETITIVIDAD
Ciemat
Centro de Investigaciones Energéticas, Medioambientales y Tecnológicas

The status and challenges of internal dosimetry (technical aspects)

María Antonia López

CIEMAT – Head of Internal Dosimetry Group

Radiation Dosimetry Unit. Madrid, Spain

ma.lopez@ciemat.es

Dosimetry of internal exposures:

- The doses due to intakes of radionuclides **can not be obtained directly, but must be assessed** from:
  - **In-vivo measurement** of the **activity (Bq)** using Whole/partial Body Counters
  - **In-vitro measurements** of the **activity rate in excreta samples (Bq/day)**,
  - **Activity concentration in the air (Bq/m^3)**

  Or by a combination of these methods

- The interpretation of the monitoring data for the **assessment of the intake I(Bq) and Committed Effective Dose E(50) (mSv)** requires:
  - The application of **biokinetic and dosimetric models**,
  - The evaluator needs to know or to make assumptions about:
    - **Type of intake** (acute, chronic),
    - **Pathway of intake** (inhalation, ingestion, wound, injection)
    - **Time of intake** (elapsed time from the exposure and the measurement)
    - **Physical** (particle size) and **chemical properties** of contaminants

Dosimetry of internal exposures:

- **Annual Limit for Effective Dose** taking into account external and internal exposures **E(mSv) = Hp(10) mSv + E(50) mSv** is recommended **20 mSv/year**

$$E_t = H_P(10) + \sum_j I_{j,ing}\, e(g)_{j,ing} + \sum_j I_{j,inh}\, e(g)_{j,inh}$$

$H_P(10)$ mSv External Exposures

E(50) mSv Internal Exposures

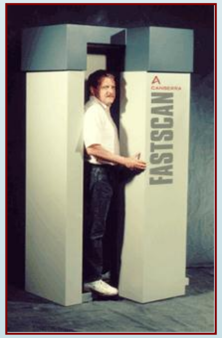
- I ing : Incorporation (Bq) by ingestion
- e(g) ing : dose coefficient mSv/Bq – ingestion
- I inh: Incorporation (Bq) by inhalation
- e(g) inh: dose coefficient mSv/Bq - inhalation

- **Individual Monitoring programs** of internal exposures should guarantee the detection of all the doses **E(50) ≥1 mSv/year** due to intakes of radionuclides at the workplace (unless the detection limit makes it unachievable, e.g. Actinides).

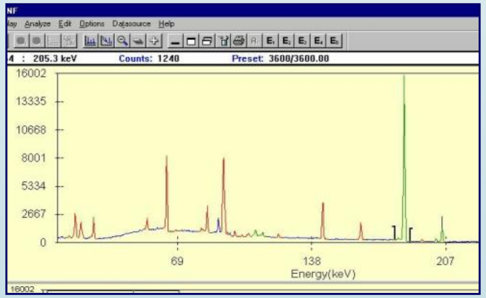
Dosimetry of internal exposures:

1.- Workplace characterization
Potential internal exposures: radionuclides, type of radiation, energy, …

2- Individual Monitoring Program: technique and frequency

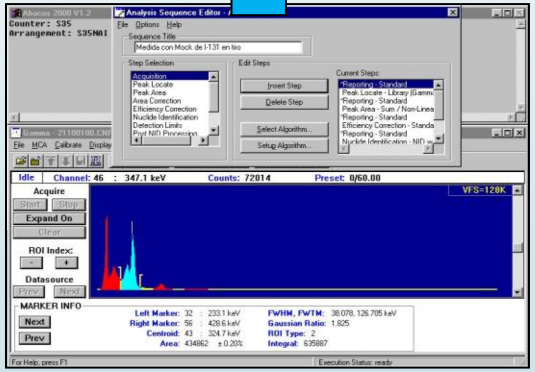


3.- Monitoring of workers: in-vivo and in-vitro methods



4.- Result of monitoring: the spectrum

5.- Analysis of data



6.- Results of spectrum analysis:

a. **Identification of radionuclides**
b. **Quantification in terms of activity M (Bq) or (Bq.d^{-1})**

7.- Interpretation of monitoring data

8.- Assessment of Intake I(Bq) and Dose E(50) mSv

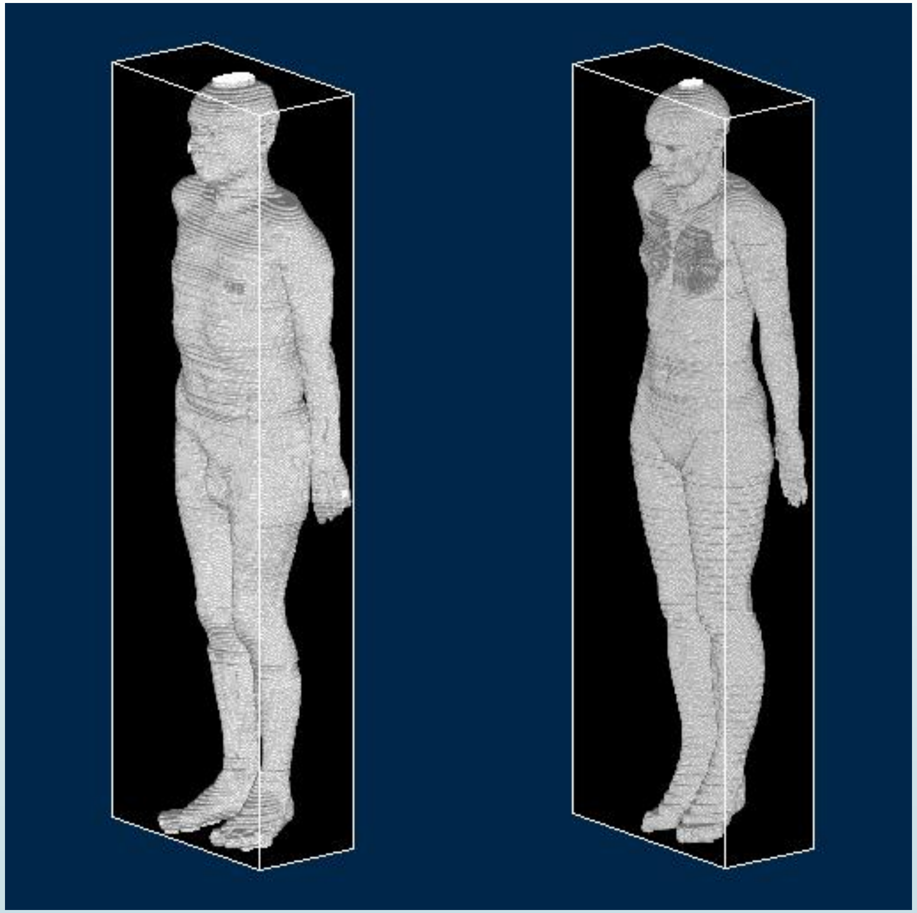
Dosimetry of internal exposures: current status

The Internal Dosimetry community dealing with occupational exposures is focused on:

- **Harmonization** of methods and tools to obtain the "best estimate" of the intake and dose due to the incorporation of radionuclides into the body (forthcoming **ICRP Reports on "Occupational Intakes of Radionuclides" (OIR**) and on **"Public Intakes of Radionuclides", IDEAS Guidelines, EC BSS and Technical Recommendations, IAEA Safety Guides, NCRP Publications**,…).
- **Normalization** for the establishment of **ISO Standards** that guarantee reliability of the results of monitoring and dose E(50) and permit accreditation of internal dosimetry laboratories
- **Networking and coordination of research** to promote collaboration of internal dosimetry experts: **EURADOS WG7** (European Radiation Dosimetry Group), **PROCORAD** Association for in-vitro monitoring, **WHO REMPAN WG** on internal dosimetry,…), **European Commission** (OPERRA, EJP on Radiological Protection), …
- **Education and Training** (IAEA, EURADOS, Devco,…).

The International Commission on Radiological Protection (ICRP)

- **2007 ICRP recommendations on radiological protection: update of W_R y W_T,** to be used in the calculation of **Effective dose**.
- **ICRP103** also requires the separate evaluation of **equivalent dose** to males and females, sex-averaging for the calculation of the effective dose for the reference person.
- ICRP adopted the **reference anatomical computational phantoms** for **male and female (ICRP103)**
- All these substantial changes implies the **revision of the dose coefficients for internal exposures**



ICRP Voxel phantoms for Reference Adult male and women

ICRP Reports: (1) OIR "Occupational Intakes of Radionuclides" (2) "Public Intakes of Radionuclides"

- (1) Forthcoming **OIR Reports**:
  - **Update of biokinetic models and dosimetric tools** that will replace ICRP30, 54, 68 and 78 publications.
  - **Revised dose coefficients for occupational intakes** by inhalation and ingestion calculated using the **ICRP100 Human Alimentary Tract Model (HATM)** and a **revision of the Publication 66 Human Respiratory Tract Model (HRTM**)
  - **Revisions** of many models for the **systemic biokinetics** of radionuclides absorbed to blood, making them more physiologically realistic representations of uptake and retention in organs and tissues and of excretion.
  - **Guidance on monitoring programs and monitoring data interpretation.**

- (2) Planned "**Public Intakes of Radionuclides**" Report: ICRP is developing a **new family of age-dependent voxel phantoms** based on work by the Univ. of Florida: **newborn, 1-year-old child, 5-year-old child, 10-year-old-child, 15-year-old female, and 15-year-old male.** These phantoms add to the already existing adult **reference male and female** phantoms. Also a phantom of a **pregnant woman** at 8 different stages of gestation is being developed **to calculate doses to foetus**

The International Organization for Standardization (ISO)

ISO has published three standards on internal dosimetry developed by ISO TC85 “Nuclear Energy” /SC2 “Radiation Protection” / **WG13 “Monitoring and dosimetry for internal exposures”**

- **ISO28218 “Performance Criteria for radiobioassay”** provides guidance on performance of radiobioassay service laboratories including criteria for establishing an appropriate quality assurance program taking into account:

(1) **Sensitivity of methods: decision threshold and detection limit**

(2) **Quality Control: relative bias (Br) and repeatability (S_{Br})**

$$B_{ri} = \frac{A_i - A_{ai}}{A_{ai}}$$

$$B_r = \sum_{i=1}^{n} \frac{B_{ri}}{n}$$

A_i = Monitoring value
A_{ai} = Reference value

$$s_{B_r} = \sqrt{\frac{\sum_{i=1}^{n}(B_{ri} - B_r)^2}{n-1}}$$

Acceptance criteria: Br (-0.25,+0.50); $S_{Br} < 0.4$

(3) Recommendations on **performance criteria** for **in vivo** radiobioassay (identification of radionuclides, quantification) and for **in-vitro** radiobioassay (+ analytical methodology). Participation in **Intercomparisons.**

(4) Requirements for **reporting and recording**.

The International Organization for Standardization (ISO)

- **ISO20553 "Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material"**
  - Requirements for the design of **suitable individual monitoring programs** to monitor workers exposed to the intake of radioactive substances at the workplace.
  - Principles for the **choice of monitoring techniques and frequency** of measurements taking into consideration the potential intake scenario and the availability and detection limits of in-vivo and in-vitro methods of internal dosimetry

- **ISO27048 "Dose Assessment for the monitoring of workers for internal radiation exposure"**
  - Guidance on the application of a **Standard Step-by-step procedure** for the **interpretation of monitoring data of workers exposed to internal exposures** to guarantee consistency and reliability in the results of **Intake I(Bq) and Committed Effective Dose E(50) mSv.**
  - This standard will help service laboratories **for accreditation or approval by authorities** (a growing demand).
  - Annexes: Analysis of **Uncertainties using Scattering Factors** (IDEAS Guidelines) and **Goodness of Fit** using **Maximum Likelihood Method and Chi^2 Test.**

The International Organization for Standardization (ISO) - DRAFTS

- **ISO/DIS 16638, draft 2014 "Monitoring and internal dosimetry for specific materials – Part 1: Uranium".**
- **ISO/DIS 16637, draft 2014 "Monitoring and internal dosimetry for staff exposed to medical radionuclides as unsealed sources".**
  - To provide guidance to the staff involved in the **diagnostic or therapeutic use of radionuclides in medicine**, of the practical application of the 3 ISO standards 28218, 20553 and 27048.
  - **Monitoring programs** proposed: Confirmatory, Triage, Routine, Special, Task-related
  - **Main risk: ^{131}I exposures** for workers in nuclear medicine, where doses may be significant.
  - **IRSN (France):** campaign of **in-situ monitoring of medical staff using mobile** units for in-vivo counting

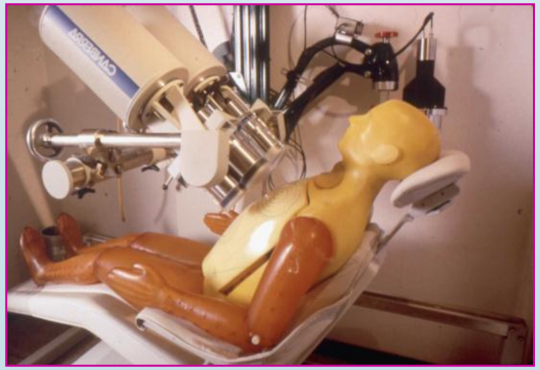
Table 1 — Most commonly used radionuclides in nuclear medicine

Radionuclides	Half-life*	Main emissions
C-11	20,39 m	$\beta+, \gamma^{i}$
O-15	122,24 s	$\beta+, \gamma^{i}$
F-18	109,77 m	e-, $\beta+, \gamma^{i}$
Ga-67	3,2612 d	e-, X, γ
Ga-68	67,71 m	$\beta+, \gamma^{i}, \gamma$
Sr-89	50,53 d	$\beta-, \gamma$
Y-90	64,10 h	$\beta-$
Tc-99m	6,015 h	e-, X, γ
In-111	2,8047 d	e-, X, γ
I-123	13,27 h	e-, X, γ
I-131	8,02070 d	e-, $\beta-$, X, γ
Sm-153	46,50 h	e-, $\beta-$, X, γ
Er-169	9,40 d	$\beta-, \gamma$
Lu-177	6,647 d	$\beta-, \gamma$
Re-186	3,7183 d	e-, $\beta-$, X, γ
Re-188	17,0040 h	e-, $\beta-$, X, γ
Tl-201	72,912 h	e-, X, γ
Ra-223	11,43 d	$\alpha, \beta-$, X, γ

*according to ICRP 107[8] γ^{i} Annihilation photons

Accreditation of in-vivo/in-vitro radiobioassay laboratories and internal dosimetry services according with ISO17025

- The aim is **to guarantee technical competence** for (1) monitoring of radionuclides incorporated in the body and (2) evaluation of Committed Effective Dose E(50) mSv.
- The international standards dealing with internal dosimetry (ISO2818, ISO27048 and ISO20553) should be taken into account in the accreditation process
- Major challenges: **Uncertainty analysis, traceability of calibration sources, validation of methods and appropriate evaluation of the sensitivity of detection**

European Commission (EC) – Basic Safety Standards (BSS)

- **Council Directive 2013/59/Euratom of 5 December 2013** lays down the **Basic Safety Standards for protection against the dangers arising from exposures to ionizing radiations**
- New EC Directive should be implemented at national level in the **legislation of EU members by February 2018.**

Article 41

Individual monitoring

1. Member States shall ensure that category A workers are systematically monitored based on individual measurements performed by a dosimetry service. In cases where category A workers are liable to receive significant internal exposure or significant exposure of the lens of the eye or extremities, an adequate system for monitoring shall be set up.

Article 81

Dosimetry services

Member State shall ensure that dosimetry services determine internal or external doses to exposed workers subject to individual monitoring, in order to record the dose in cooperation

European Commission (EC) – DG-ENER "Technical Recommendations on Internal Dosimetry ("TECHREC")

- TECHREC Project (2014-2016) **"Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides". Ref ENER/2014/NUCL/SI2.680087**

  - ✓ A consortium has been establishes by **EURADOS** (EUropean RAdiation DOSimetry Group e.V.) and 7 European institutions **(BfS-Germany, CEA-France, CIEMAT-Spain, ENEA-Italy, IRSN-France, KIT-Germany and PHE-United Kinngdom**) with the contribution of 11 experts, in charge of elaborating the Technical Recommendations for Internal Dosimetry

  - ✓ The purpose of **TECHREC** is developing guidelines and recommendations to authorities and public/private institutions in those aspects of the implementation of **European Directive 2013/59/EURATOM** related with the monitoring and dose assessment of occupational internal exposures **and the harmonization in procedures.**

European Commission (EC) – DG-ENER
"Technical Recommendations on Internal Dosimetry ("TECHREC")

- **TECHREC (2014-2016) .** Final Report will include:
  - **Operational and dosimetric quantities**
  - **Biokinetic and dosimetric models**
  - **Individual Monitoring**
  - **Methodology for the assessment of Intake and Committed Effective Dose E(50),**
  - **Individual Monitoring Programs**
  - **Wound Dosimetry**
  - **Assessment of doses when administration of decorporation therapy**
  - **Reliability and uncertainties**
  - **Quality Assurance and Quality Control**
  - **Accreditation and certification according with ISO/IEC Standards**
  - **Participation in intercomparisons**
  - **Requirements for the authorization of internal dosimetry services**
  - **Annexes: (1) radon dosimetry for workers, (2) internal dosimetry for workers after a major accident at a nuclear facility and (3) internal dosimetry for assessment of risk to health.**

- **Identification of Stakeholders** and invitation to participate in the revisión of the document

- **TECHREC Report: EC-Radiation Protection publication, open access at EC web site (2016)**

IDEAS Guidelines - version 2 – for the estimation of Committed Doses from Incorporation Monitoring Data - EURADOS Report 01-2013

Intercomparison exercises on internal dose assessments in the past have shown a **wide range in the results of estimated doses provided by the participants, obtained from the same monitoring data set**, depending on assumptions of the exposure scenario and the biokinetic and dosimetric models applied,

Hence the need for **guidance on harmonising evaluations of internal exposures**. **IDEAS Guidelines** are based on a general philosophy of:

- **Harmonisation**: any two assessors should obtain the same estimate of dose from a given data set.
- **Accuracy**: the "best" estimate of dose should be obtained from the available data.
- **Proportionality**: the effort applied to the evaluation should be proportionate to the dose

IDEAS Guidelines - version 2 – for the estimation of Committed Doses from Incorporation Monitoring Data - EURADOS Report 01-2013

IDEAS GL use a "Levels of Task" to structure the approach to a E(50) evaluation:

- **Level 0 (annual doses < 0.1 mSv,** no dose evaluation required;
- **Level 1** (Simple evaluation using ICRP reference parameter values (**typical dose: 0.1 – 1 mSv);**
- **Level 2:** advance evaluation using additional information as a result of an investigation for a more realistic assessment **(typical dose: 1- 6 mSv)** and
- **Level 3**: more sophisticated evaluation by an expert (**typical dose > 6 mSv).**

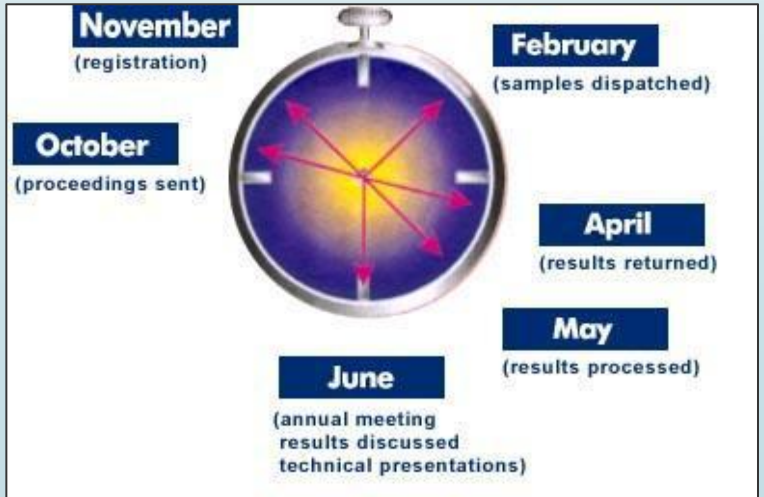
UNCERTAINTIES: Measurements are assumed to be log-normally distributed with a given **scattering factor (SF) that takes into account Type A and Type B** sources of uncertainties:

$$SF_i = \exp\sqrt{[\ln(SF_A)]^2 + [\ln(SF_B)]^2}$$

Same approach is **adopted by ISO27048** (Values of SF in Annex A, Tables B)

Intercomparisons of in-vitro monitoring of internal emitters: PROCORAD Association (www.procorad.org)

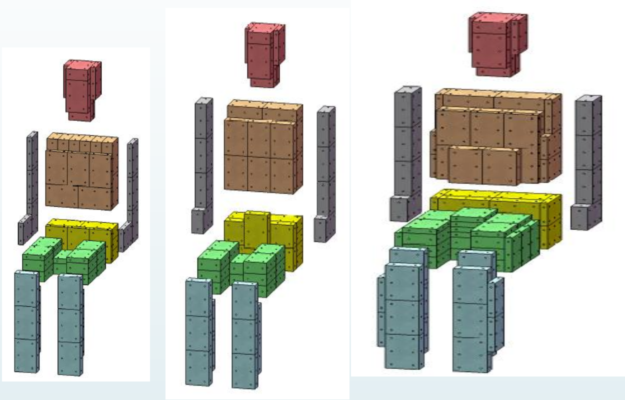
- **PROCORAD** is a **European organization of laboratories** dealing with **in vitro measurements of radionuclides in excreta samples**.
- The main activity of this group is the organization **of regular intercomparisons** of measurements to promote fruitful scientific and technical exchanges between its members. Laboratories from Europe and from outside Europe are regular participants of this exercise.
- A scientific meeting is organized each year during the Association's General Assembly, alternately in France and abroad. A technical report is published each year in French and in English. **Next Meeting : Toledo (Spain) June 17-19, 2015.**



IRSN Intercomparisons of in-vivo monitoring of internal emitters

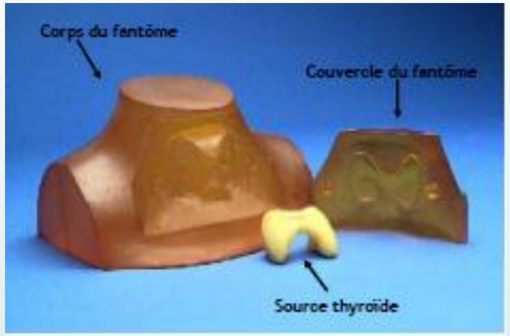
- **Annual Organization, 3 programs:**

(1) Gamma emitters in total body
(2) Lung Counting and (3) radioiodine in thyroid

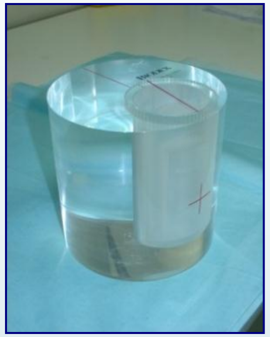


IRSN Brick Phantoms: Female (50 kg), Standard Man (70 kg) and Big Man (90 kg)

IRSN Livermore Thyroid phantom



ANSI Calibration phantom



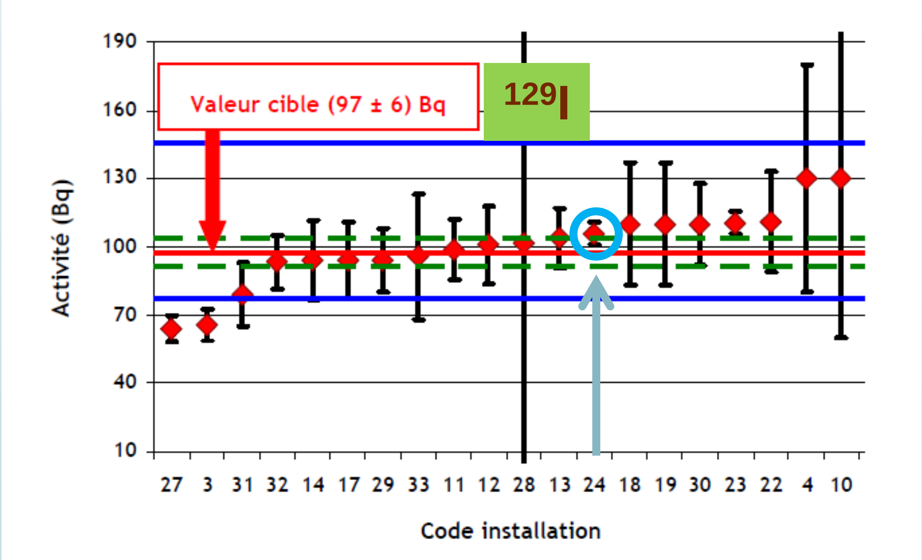
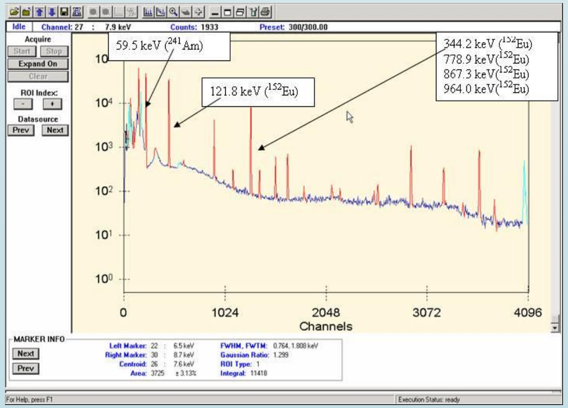


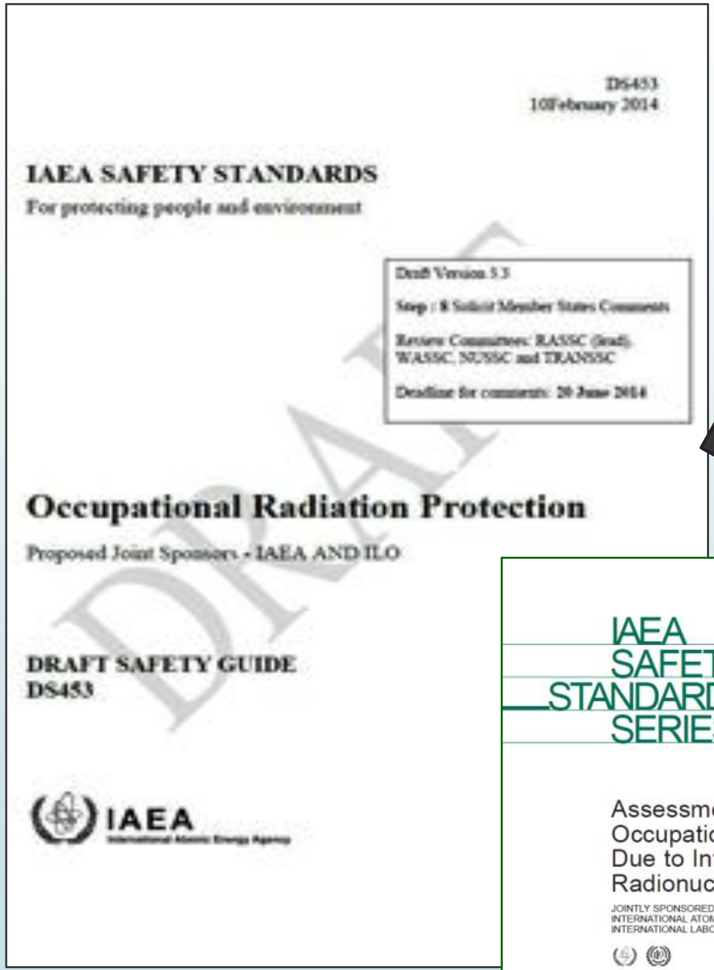
Figure 5 : Présentation graphique des résultats pour la mesure du fantôme 1



BOMAB Calibration phantom

International Atomic Energy Agency (IAEA)

- **Draft IAEA Safety Guide on Occupational Radiation Protection (DS453**) is prepared based on the revised [Radiation Protection and Safety of Radiation Sources:International Basic Safety Standards (GSR Part 3, 2014)].
- It combines all the relevant safety guides on the protection of workers into a **single comprehensive safety guide, including the existing Safety Guide RS-G-1.2 Assessment of Occupational Exposure due to Intakes of Radionuclides (1999**) which will be superseded once the draft is approved for publication.



DS453
10 February 2014

IAEA SAFETY STANDARDS
For protecting people and environment

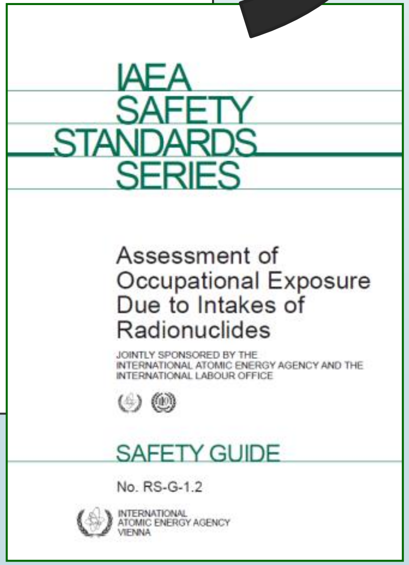
Draft Version 5.3
Step : 8 Solicit Member States Comments
Review Committees: RASSC (lead), WASSC, NUSSC and TRANSSC
Deadline for comments: 20 June 2014

DRAFT

Occupational Radiation Protection
Proposed Joint Sponsors - IAEA AND ILO

DRAFT SAFETY GUIDE
DS453

IAEA



IAEA SAFETY STANDARDS SERIES

Assessment of Occupational Exposure Due to Intakes of Radionuclides

JOINTLY SPONSORED BY THE INTERNATIONAL ATOMIC ENERGY AGENCY AND THE INTERNATIONAL LABOUR OFFICE

SAFETY GUIDE
No. RS-G-1.2

INTERNATIONAL ATOMIC ENERGY AGENCY
VIENNA

World Health Organization (WHO) / Radiation Emergency Medical Preparedness and Assistance Network (REMPAN)

- The **WHO REMPAN Internal Contamination Working Group InRadCon** is recently established with the aim to conduct collaborative projects to fill the knowledge and operational gaps in the management of internal radiation exposures following a radiological or nuclear emergency event.
- Priorities have been established to improve procedures and tools and to minimize the health risk. Main topics:
  - emergency monitoring of population
  - internal radiation dose assessment
  - medical treatment and management

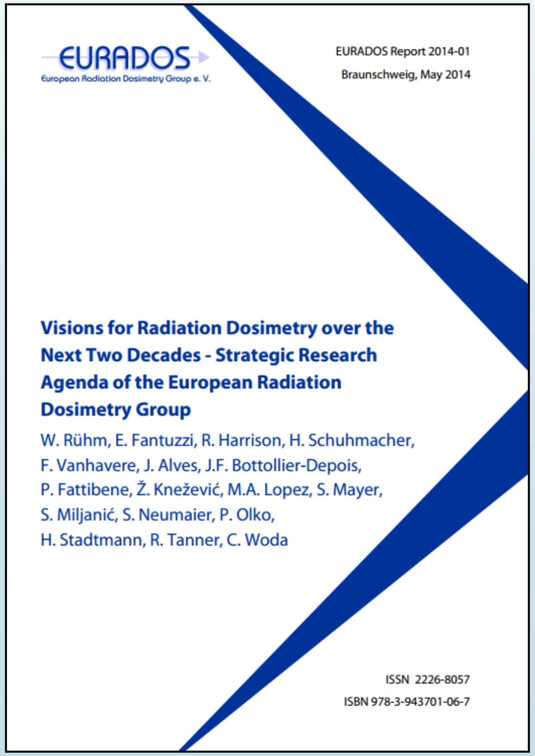
Members: Centers for Disease Control and Prevention **(USA)**, WHO **(Switzerland)**, PHE **(UK)**, IRSN **(France)**, Burnasyan Federal Medical Biophysical Center of Federal Medical, Biological Agency **(Russia)**, NIRS **(Japan)**, Health **Canada**, CIEMAT **(Spain)**, CEA (France), IRD (**Brazil**), Australian Radiation Protection and Nuclear Safety Agency, (**Australia**), Chinese Center for Disease Control and Prevention **(China)**

EURADOS e.V. – European Radiation Dosimetry Group

- **EURADOS:** European organisation of 61 laboratories and institutions (Voting Members) and more than 500 Associate members in the field of dosimetry of ionising radiations

EURADOS Strategic Research Agenda "SRA" was published in 2014 **with 5 Visions and associated challenges** (**EURADOS Report 2014-01):**

- Visión 1: **Towards Updated Dose Concepts and Quantities**
- Visión 2: **Towards Improved Radiation Risk Estimates deduced Epidemiological Cohorts**
- Visión 3: **Towards an Efficient Dose Assessment in Case of Radiological Emergencies**
- Visión 4: **Towards an Integrated Personalized Dosimetry in Medical Applications**
- Visión 5: **Towards an Improved Radiation Protection of Workers the Public**


EURADOS
European Radiation Dosimetry Group e. V.
EURADOS Report 2014-01
Braunschweig, May 2014

Visions for Radiation Dosimetry over the Next Two Decades - Strategic Research Agenda of the European Radiation Dosimetry Group

W. Rühm, E. Fantuzzi, R. Harrison, H. Schuhmacher, F. Vanhavere, J. Alves, J.F. Bottollier-Depois, P. Fattibene, Ž. Knežević, M.A. Lopez, S. Mayer, S. Miljanić, S. Neumaier, P. Olko, H. Stadtmann, R. Tanner, C. Woda

ISSN 2226-8057
ISBN 978-3-943701-06-7

www.eurados.org

EURADOS WG7 "Internal Dosimetry" – Work Plan

- **Harmonization** on internal dose assessments (e.g. **IDEAS Guidelines**)
  - **TECHREC Project** – Technical recommendations for internal dosimetry services
  - EURADOS **Dose Assessment Intercomparison** after publication of TECHREC and OIR
- Implementation and Quality Assurance of Biokinetic Models.
  - Development of a **Guide for the implementation of new ICRP/OIR Biokinetic Models**
  - To implement a **more physiological approach to biokinetic models to allow the study of non-cancer effects**, e.g. vascular diseases, by including blood as compartment in the biokinetic models
- **Individual monitoring of internal exposures and application of Monte Carlo (MC) methods and voxel phantoms to in-vivo monitoring**
  - Lessons learned after the Fukushima Daaichi NPP accident: **to improve individual monitoring and dose assessment in case of RN emergency**, including more rapid methods for in-vitro monitoring and appropriate in-vivo calibration factors for children
- **Microdosimetry** of internal emitters
- Study of **biological dosimetry vs. internal dosimetry** in cases of **accidental intakes**
- **Education and training** on internal dosimetry

MoU of European Platforms on Radiological Protection for the consolidation of a strategic vision **for radiation protection research in Europe** :

- **MELODI:**
  MULTIDISCIPLINARY EUROPEAN LOW DOSE INITIATIVE
- **ALLIANCE:**
  EUROPEAN RADIOECOLOGY ALLIANCE
- **NERIS**
  EUROPEAN PLATFORM ON PREPAREDNESS FOR NUCLEAR AND RADIOLOGICAL EMERGENCY RESPONSE RECOVERY
- **EURADOS**
  EUROPEAN RADIATION DOSIMETRY GROUP

HORIZON 2020

European Joint Program (EJP)
In Radiation Protection
H2020 call NFRP 07 – 2015
Integrating radiation research in the European Union

OPERRA:

OPEN PROJECT FOR EUROPEAN RESEARCH AREA
2nd OPERRA call: December 2014

CONCLUSIONS - **Main challenges identified in the frame of internal dosimetry:**

- **Implementation of OIR biokinetic models (ICRP)** for the evaluation of occupational internal exposures
- Improvement in monitoring (in-vivo, in-vitro), dose evaluation and management (people, samples, communication) in case of **radiological/nuclear emergency events**
- **Accreditation** of internal dosimetry laboratories/services **according with ISO17025**
- Dosimetry of **medical staff at risk of intake of radionuclides in the workplace**
- Application of new tools for in-vivo monitoring of internal exposures: **Monte Carlo calibration using voxel/NURBS phantoms**
- **Networking and Multidisciplinary research:**
  - ***e.g. CURE Project- "Concerted Action for an Integrated (biology – dosimetry - epidemiology) Research project on Occupational Uranium Exposure".*** DoReMi 2nd call (2013-2015)
  - Development of biokinetic models physiciologically more realistic for the **study of non-cancer effects of internal exposures and for radiopharmaceuticals.**

Thanks for your attention