61st HPS Meeting - USTUR: Five Decade Follow-up of Plutonium and Uranium Workers

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

EURADOS – USTUR collaboration

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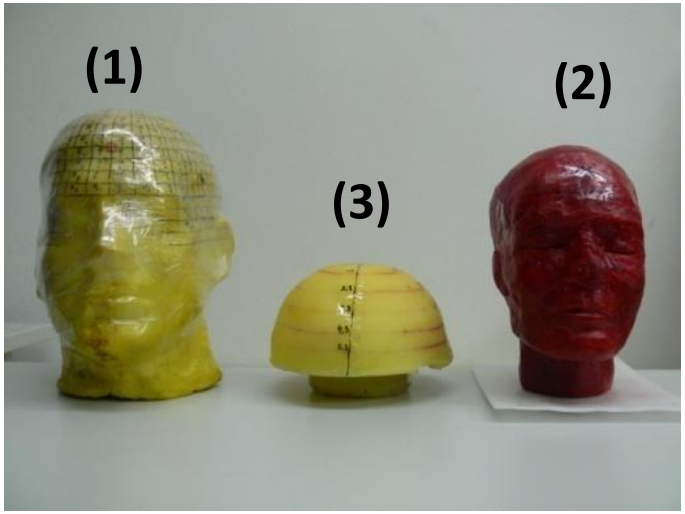
EURADOS - European Radiation Dosimetry Group www.eurados.org

"Learning from Plutonium and Uranium Workers"

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

- An international intercomparison was organized by the Working Group 7 "Internal Dosimetry" of **European Radiation Dosimetry Group EURADOS e.V.** for the measurement of Americium in 3 skull phantoms using Ge detectors



(1) USTUR Case w0102 skull phantom,
(2) BfS head phantom
(3) CSR skull phantom

EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

- The exercise counted with the participation of **12 laboratories**, **10 from Europe and 2 from North America.**

- **Transport of the 3 phantoms:**

  HMGU (Germany)→ BfS (Germany) → KIT (Germany)

  → NRPI (Czech Republic)

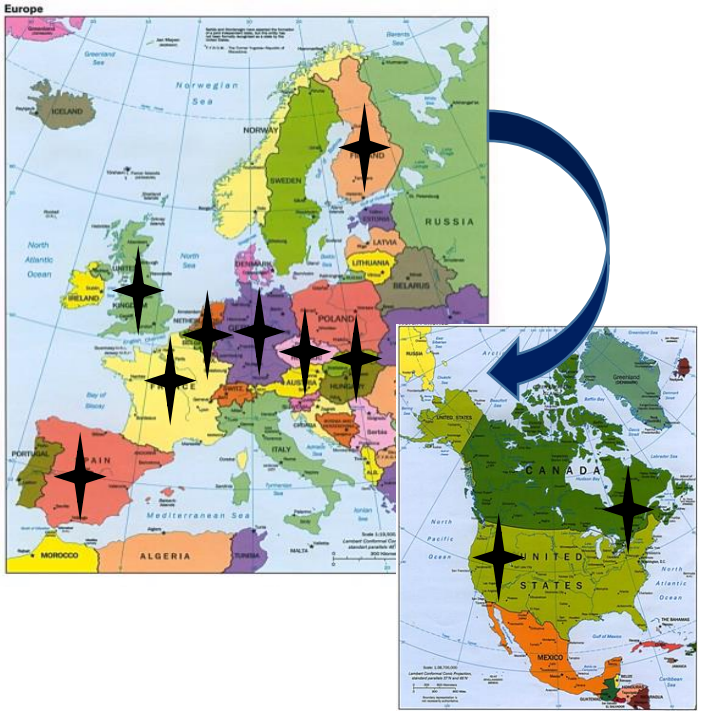
  → SZU (Slovakia)

  → SCK-CEN (Belgium)

  → IRSN (France)→ CIEMAT(Spain)

  → PHE (UK) → STUK (Finland)

  → Health Canada → MSAR (USA)



EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

- The **main objectives** of the **measurement exercise** were:
  Coordinator: P. Nogueira, HMGU, Germany

  - ✓ to compare the results of **counting efficiency in fixed positions** over each head phantom **(Task 1)**
  - ✓ the estimation of the **activity of Americium in the skulls (Task 2).**
  - ✓ **to compare the phantoms it selves** and to test if they fulfill appropriate features **as calibration sources** representing the contamination of Americium in human head bone.

- A **Monte Carlo (MC) intercomparison** was organized in parallel with measurement exercise, using the **voxel representations of the 3 physical phantoms**
  Coordinator: T.Vrba (CTU-Prage, Czech Republic)

EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

- **Americium** is a radiotoxic **bone-surface seeker radionuclide**
  radiological half-life of 432.6 years,
  biological half-life in the skeleton of 46.6 years (ICRP78)
- In case of americium intake: ^{241}Am is usually evaluated by **in-vitro monitoring of excreta** samples (α spectrometry)

- **In vivo monitoring** may be used for the detection of 59.5 keV photons of ^{241}Am in **lungs and bone** (knee or skull) with Ge detectors (γ spectrometry).

  ✓ **Appropriate anthropomorfic phantoms** simulating retention of ^{241}Am in this part of the body are required **for calibration**

EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

SKULL PHANTOMS OF EURADOS INTERCOMPARISON

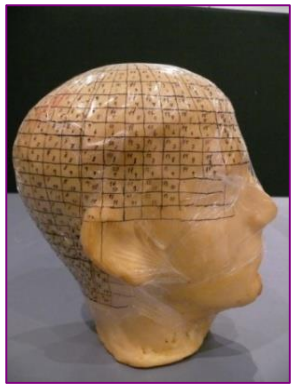
- The **BfS skull phantom** was fabricated by the New York Medical Center (USA) for the Federal Office of Radiation Protection (BfS, Germany)
- The phantom contains **real human bone artificially labelled with ^{241}Am** in its inner and outside sides (Laurer 1993)

- Interior of the phantom: paraffin wax
- Outside of the phantom: wax of 6 mm thickness
- **A= 5239 Bq ^{41}Am (2012) 3σ= ± 2.1%**

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

SKULL PHANTOMS OF EURADOS INTERCOMPARISON (cont.)

- **The BPAM phantom from USTUR** (United States Transuranium and Uranium Registries) is part of the **skeleton of the first USTUR whole-body donor (Case No 102)**
- **Half of the skull was really contaminated** due to an accidental intake of Americium by a U.S. worker 25 years before his death; the other half is real human bone from non-contaminated person.

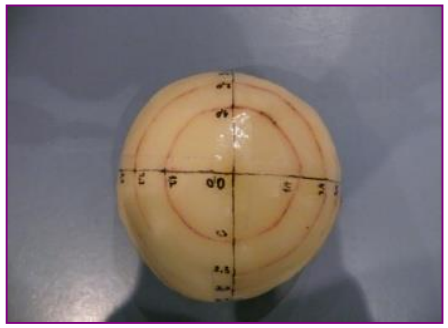


- The skull was filled and covered with tissue equivalent material (Hickman and Cohen 1988).
- **A= 287.2 ± 3.7 Bq (2012)** Tolmachev, 2012

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

SKULL PHANTOMS OF EURADOS INTERCOMPARISON (cont.)

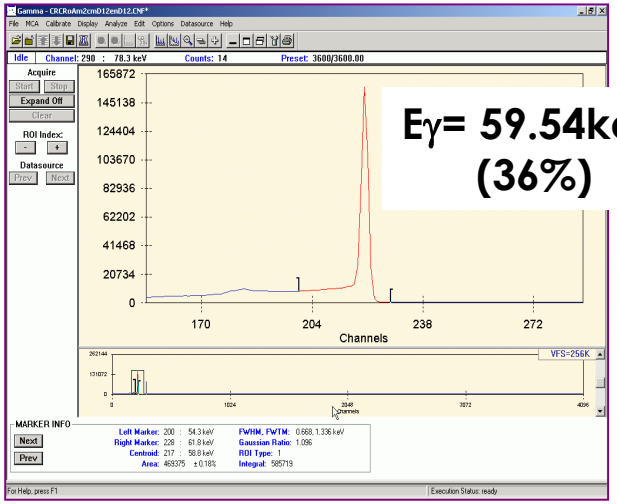
- **CSR phantom** was fabricated by NRPI (Czech Rep.) and SZU (Slovakia) as a simple hemisphere of equivalent bone and tissue material representing the top of a human head
- **A= 981.4 Bq (2012) σ = 6%** (Vrba 2014)
- The main use of the phantom: validation of counting efficiency for the Monte Carlo study for a simple counting geometry



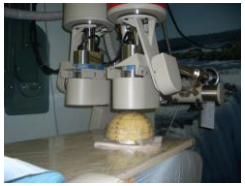
EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

Task 1.- Measurements of the 3 phantoms to obtain Counting Efficiency (cps/Bq) of ^{241}Am using **one Ge detector over each skull in different positions** (γ spectrometry)

$$Eff\,(cps/Bq) = \frac{Area(n^o\,counts)_{E=59.5keV}/t(s)}{Activ_{skull}(Bq)}$$



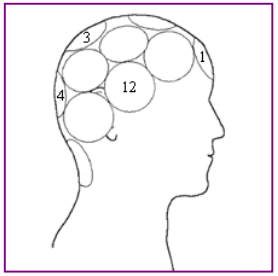
1.- Measurement of CSR phantom

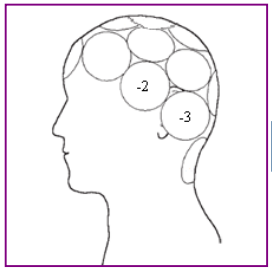


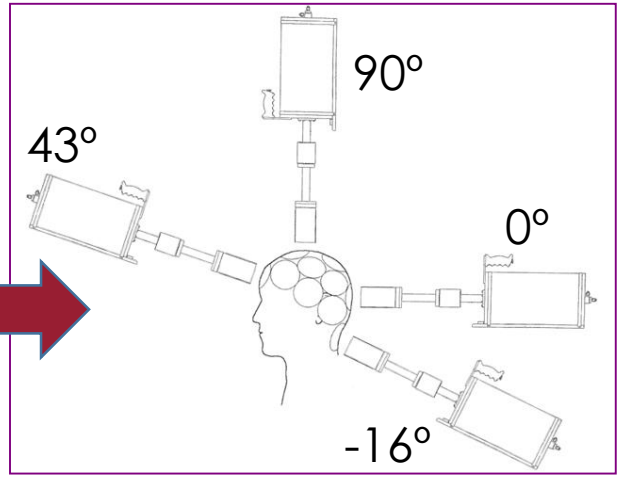
- Only vertical position P0
- Simple detection geometry

2.- Measurements of BfS and USTUR phantoms: positions Pi, i= 1,…n defined in the protocol

Distance d= 1cm
Detector-phantom







EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

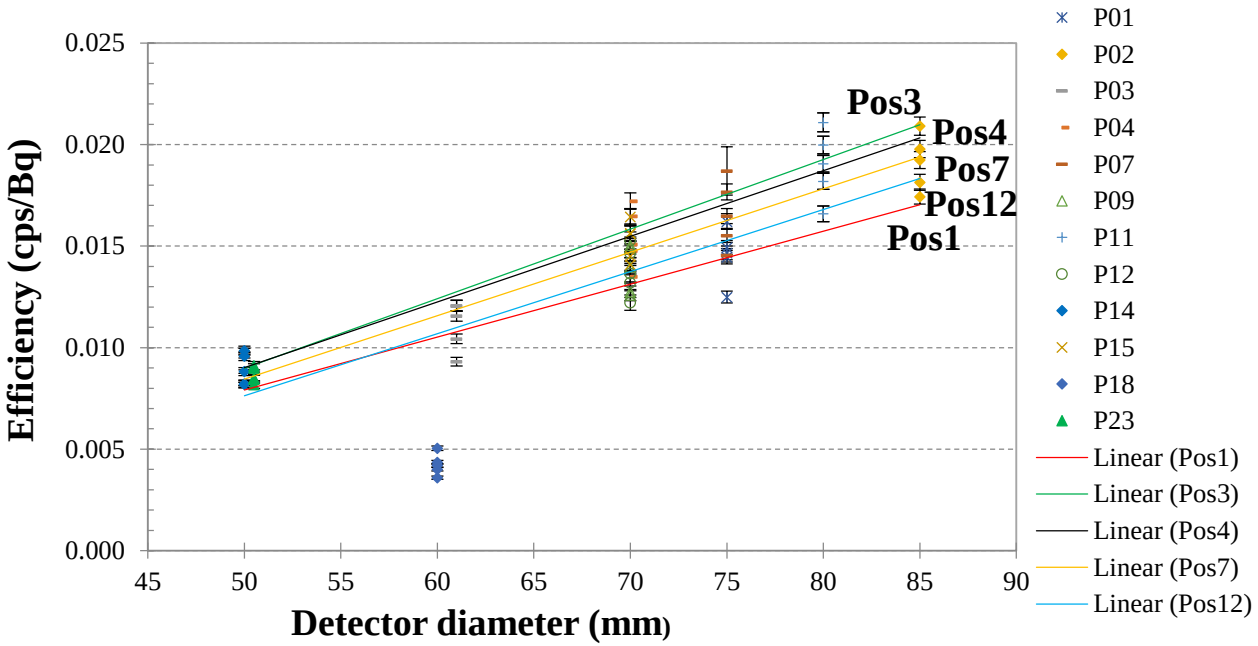
12 Participants of Task 1- Detector systems

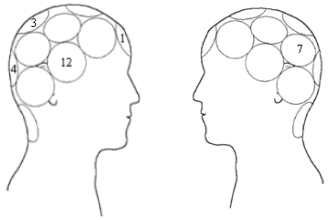
Participant number	Detector Number	Detector Type	Germanium Crystal Manufacturer	Germanium Crystal Active area (mm^2)	Germanium Crystal Diameter (mm)	Window Length (mm)	Window Material	Window Thickness (mm)
P01	3	BEGe	Canberra	4418	75	20	carbon fiber	Unknown
P02	4	GEM	Ortec	5675	85	30	carbon fiber	0.76
P03	2	LEGE	Canberra	2922	61	20	carbonfiber	0.5
P04	4	LO-AX	Ortec	3848	70	30	carbon fiber	0.76
		LO-AX	Ortec	3848	70	30	beryllium	0.5
		BEGe	Canberra	3848	70	25	carbon fiber	0.6
		GEM-FX	Ortec	3848	70	27.6	carbon fiber	0.9
P07	4	XtRa	Canberra	4418	75	72	carbon fiber	0.5
P09	2	HPGe	Canberra	3848	70	20	carbon fiber	0.6
				3848	70	30	carbon fiber	0.6
P11	2	BEGe	Canberra	5027	80	30	carbonfiber	1.6
P12	4	GEM-FX	Ortec	3848	70	25	carbon fiber	0.76
P14	4	EGM2000	Eurisys Canberra	1963	50	10	carbon fiber	1.1
		EGM2000	Eurisys Canberra	1963	50	10	carbon fiber	1.1
		Be5020	Canberra	5153	81	22	carbonfiber	0.5
		LOAX	EG&G Ortec	3926	70.7	29.5	carbon fiber	0.76
P15	4	LEGe	Canberra	3848	70	25	carbonfiber	0.5
				3848	70	30	carbon fiber	0.6
P18	1	GX-4018	Canberra Packard	2827	60	66	aluminium	1.5
P23	4	HPGe	Canberra	2003	50.5	20	carbonfiber	0.5

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

Results Task 1 (BfS phantom)

✓ **59.54 keV detection efficiency (cps/Bq)** depending on **Ge detector diameter and position over the phantom** (Nogueira et al 2015)





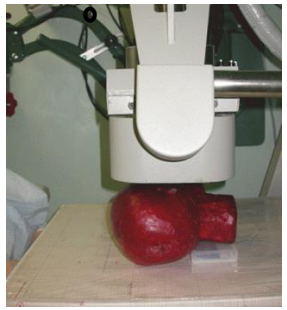
Position	Inclination
Pos1	43º
Pos3	57º
Pos4	0º
Pos7	0º
Pos12	0º

Pos1/43º

Pos3/57º Maximum Effic

Pos4/0º

Pos12/0

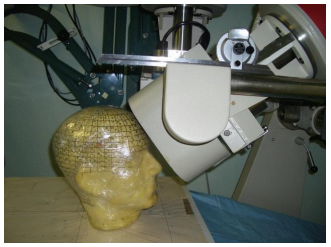


Pos7/0º

EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

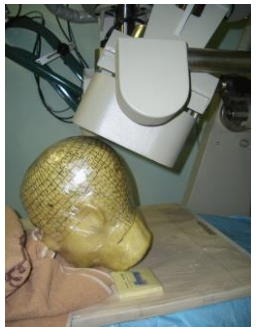
Results Task 1 (USTUR phantom)

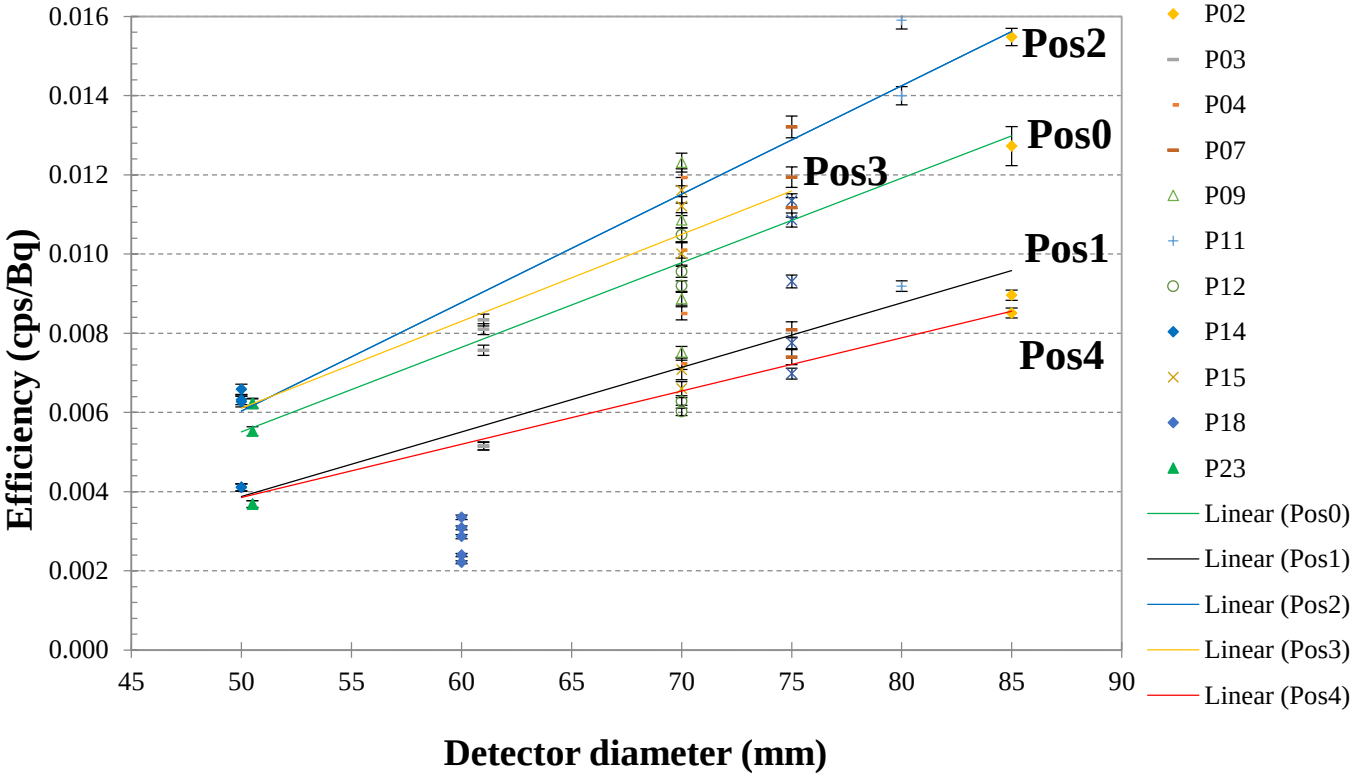
✓ **59.54 keV counting efficiency depending on det position and diameter**

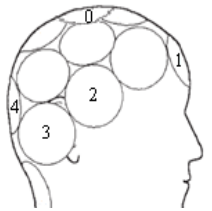
P2/0° MaxEffic



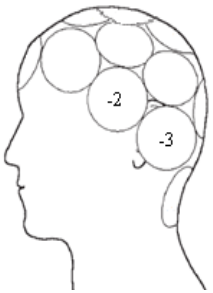




Position	Inclination
Pos0	90°
Pos1	34.5°
Pos2 and -2	0°
Pos3 and -3	-16.8
Pos4	26.5°



Contaminated side



Non-contaminated side

EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

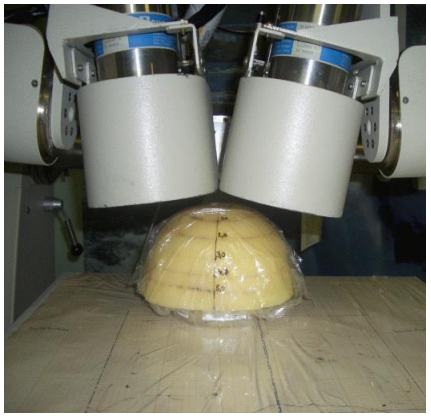
Task 2.- Measurements of the 3 phantoms to obtain Activity of ^{241}Am

$$Activity(Bq) = \frac{Area(n^{o}\,counts)_{E=59.5keV} / t(s)}{Efficiency(cpsBq)}$$

- ✓ Only 6 participants provided results of Activity for Task 2
- ✓ Each participant used own counting geometry and calibration phantom
- ✓ Head phantoms used for calibration ≠ skull phantoms from intercomp.
- ✓ 3 participants performed Efficiency calib. using MC and voxel phantoms

Example: Participant CIEMAT (Spain), counting geometry with 4 LE Ge detectors and COHEN Phantom for calibration (NY Medical Centre)





EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

Results of Task 2.- Activity of ^{241}Am of the 3 skull phantoms

Participant	Phantom	Activity (Bq)	Uncertainty (Bq)	Calibration phantom	Ratio to true Activity
P04	USTUR	309	30.9	38 year-old woman voxel phantom (Monte Carlo Calibration)	**1.08**
	BfS	7800	780		**1.49**
	CSR	1860	NP		**1.90**
P07	USTUR	501	NP	ICRP reference man	**1.74**
	BfS	18000	NP	ICRP reference woman	**3.44**
	CSR	NP	NP	(Monte Carlo Calibration)	**-**
P09	USTUR	220	11	UCIN skull phantom (Univ. Cincinnati)	**0.77**
	BfS	7800	400		**1.49**
	CSR	NP	NP		**-**
P12	USTUR	339	NP	Two Hickman skull phantoms	**1.18**
	BfS	9693	NP		**1.85**
	CSR	NP	NP		**-**
P14	USTUR	437	52	MAX-06 voxel phantom (Monte Carlo Calibration)	**1.52**
	BfS	15979	1917		**3.05**
	CSR	5588	670		**5.69**
P15	USTUR	299.6	NP	Cohen phantom	**1.04**
	BfS	12702.2	NP		**2.42**
	CSR	3217.4	NP		**3.28**

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EURADOS Intercomparison (2012-2013) on Monte Carlo modeling for the in-vivo monitoring of 241Am in Skull phantoms.

Date: 20/09/12

EURADOS WG7-WG6 joint collaboration.

This International intercomparison aims at investigating and comparing the different approaches adopted in the use and set up of voxel phantoms and Monte Carlo (MC) simulation techniques to calibrate whole body counting systems for the measurement of 241Am activity in the skull.

The exercise consists of three tasks, with increasing complexity. Three voxel phantoms will be provided to the participants with the description on materials, density and indication of the source regions. The most prominent issue of the action can be express in the question: "How close can be MC simulation to the real measurement for real geometry?".

The access of the web site (https://behounek.fjfi.cvut.cz/course/view.php?id=57) to download the protocol and the material required to solve the exercise will be provided by the coordinator of this action: Tomas Vrba(*). No fee is required and the deadlines are established as follows:

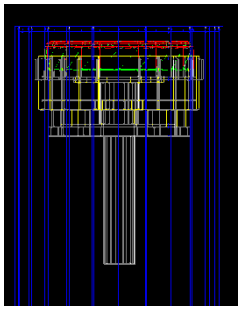
1.- Task 1: 31/12/2012
2.- Task 2: 28/02/2013
3.- Task 3: 30/04/2013

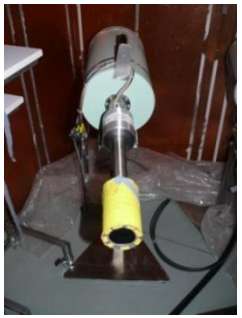
The results of this action will be disseminated in a joint international peer-review publication, the same as the two former EURADOS MC Intercomparisons on in-vivo monitoring of radionuclides(1)(2)

(*) Persons interested in this exercise should contact:
Tomas Vrba
EURADOS WG7 "Internal Dosimetry"

EURADOS Intercomparison on **Monte Carlo simulations** of measurements of ^{241}Am in skull phantoms

- **MC intercomparison**: **voxel representations of the 3 physical phantoms. 16 participants.**
- **Three tasks** were identified with **increasing difficulty.**
- **Task 1:** MC simulation of CSR hemisphere and HMGU Ge detector for calculating the counting efficiency for 59.54keV photons of ^{241}Am in an established measurement geometry.

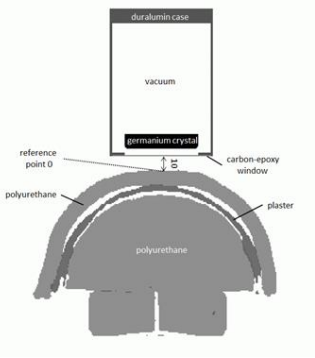




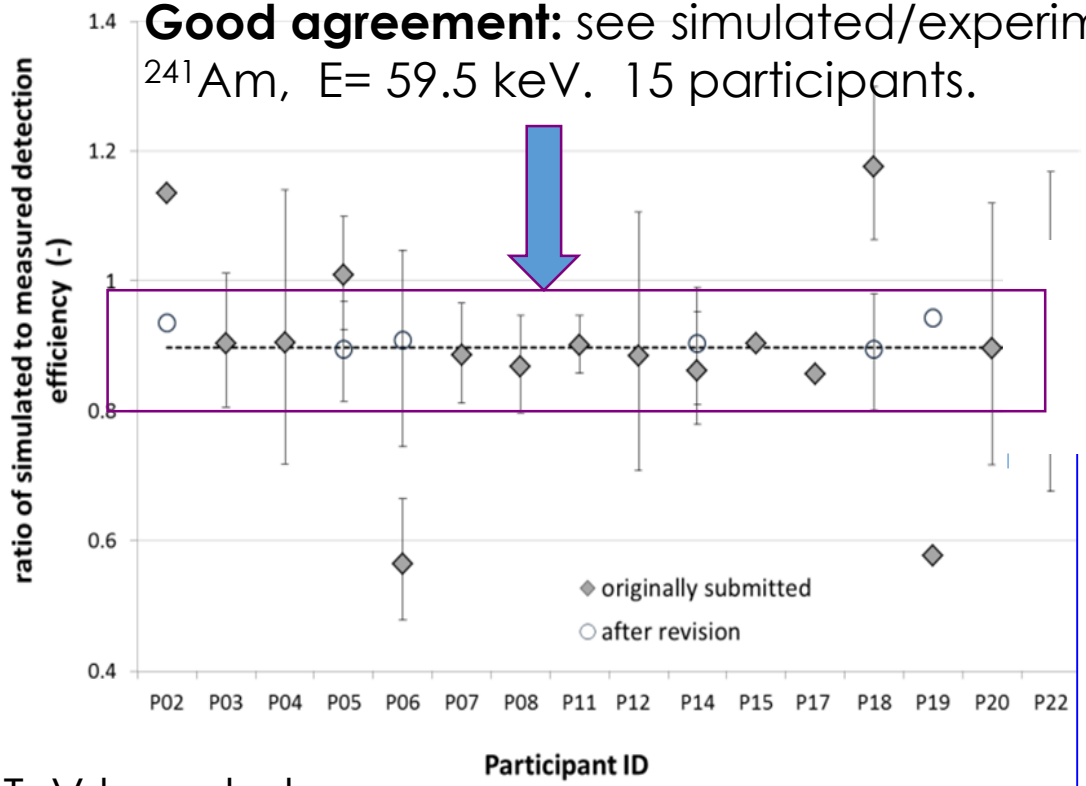
- **Task 2:** MC Modeling of the detector in the laboratory of the participant in counting geometries defined for the measurement Intercomparison. Calibration factors by MC are compared with measurements.
- **Task 3:** MC simulation of the whole detection process specific of each participant. To calculate calibration factor by modeling the detector system in the counting geometry to be used for the monitoring of a real contaminated person

EURADOS Intercomparison on **Monte Carlo simulations** of measurements of ^{241}Am in skull phantoms

Results Task 1: MC Simulation of spectrum and counting fficiency for ^{241}Am in CSR voxel phantom with 1 HPGe detector



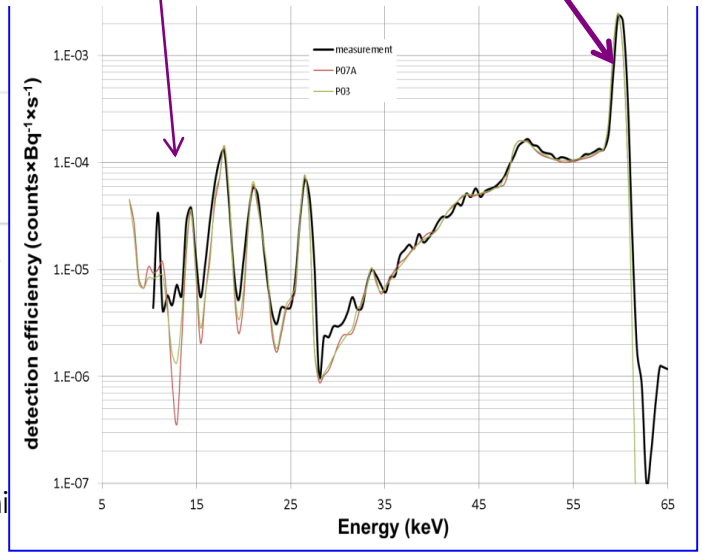
Good agreement: see simulated/experimental Eff ^{241}Am, E= 59.5 keV. 15 participants.



T. Vrba et al,
Radiation Physics and Chemistry, 2014

Experimental Spectrum
MC Spectrum

RX **Eγ= 59.5 keV**



EURADOS Intercomparison on measurements of ^{241}Am in skull phantoms

- **Results Task 2** (modelling the detector from participant lab.)
  - **Good agreement in measured spectra vs. simulated spectra** in counting positions over CSR and USTUR phantoms. Slightly worse results for BfS phantom.
  - **Ratios of simulated vs measured efficiency** for E= 59.5 kev of ^{241}Am not exceed ±12% discrepancy, **most of cases are within ±6%. Good agreement**.

- **Results Task 3** (modelling real counting geometries for the measurement of contaminated people in the participant lab.)
  - Opportunity to study monitoring methods of in vivo labs around the world.
  - Different arrangements (single/multiple detectors) and detector-head distances were used. **Very good agreement in measured vs. simulated efficiency (< ±7%).**

Conclusions

- EURADOS intercomparisons (measurements and MC simulation) were launched with the objective of providing tools to participants to evaluate the variability on counting efficiency and assessed activity due to the use of different skull phantoms.

Measurement Intercomparison:

- **Task 1:** Good agreement was found among the results of 12 participants: **relative deviations <15% for the BfS phantom** and **<17% for the USTUR phantom** when the **counting efficiencies in defined positions were compared**
- **Task 2:** The **^{241}Am activities** calculated by 6 participants **using their own calibration phantom/factor, showed discrepancies up to a factor of 3.4**, mainly due to the physical differences between the calibration phantom and the phantoms used in EURADOS intercomparison (activity distribution, skull size and filling,…)

Monte Carlo Intercomparison:

- **Good agreement in simulated vs measured spectra & counting efficiency**

- The 3 phantoms differ in shape, size and weight. No one fulfils the requirements of a standard calibration source for the calibration of HPGe detectors for the measurement of ^{241}Am in the skull of standard male worker

AKNOWLEDGMENT- Participants

EURADOS Intercomparison on measurements of ^{241}Am in 3 skull phantoms

- **S. Y. Tolmachev, USTUR, USA**
- **P. Nogueira, W. Rühm, HMGU, Germany**
- **T. Vrba, CTU-Prague, Czech Republic**
- J. F. Navarro-Amaro, B. Pérez-López, CIEMAT, Spain
- W. Buchholz, BfS, Germany
- I. Malátova , P. Fojtík, K. Fantinova, SURO, Czech Republic
- G. Etherington, J. Scott, A. Shutt, PHE, UK
- D. Franck , D. Broggio, IRSN, France
- J. Huikari, STUK, Finland
- T. Lynch, Mission Support Allince, Richland –WA, USA
- A. Lebacq, SCK-CEN, Belgium
- C. Li, B. Hauck, K. Capello, HML, Health Canada
- J. Ośko, T. Pliszczyński, NCBJ, Poland
- B. Breustedt, D. Leone, O. Marzocchi , KIT, Germany

Training course on Monte Carlo methods for the calibration of body counters

November 25-27, 2013 – KIT Karlsruhe, Germany

http://eurados.ine.kit.edu

Purpose

The Monte Carlo method is a numerical simulation technique that can be used to extend the scope of calibrations performed in *in vivo* monitoring laboratories. These methods allow calibrations to be made for a much wider range of body shapes and sizes (including children) than would be feasible using physical phantoms. Karlsruhe Institute of Technology (KIT) and the European Radiation Dosimetry Group – Working Group 7 „Internal Dosimetry" (EURADOS WG7) is organizing a training course focusing on the application of Monte Carlo methods for the calibration of whole and partial body counters.

Topics

It will be hands-on-training, centered on an exercise in KIT's *in vivo* lab which will guide the participants through all steps of a Monte Carlo calibration of an *in vivo* counter using voxel phantoms. Lecturers and tutors will be known experts on Monte Carlo methods and *in vivo* monitoring from European Institutions collaborating in EURADOS working groups on computational (WG6) and internal dosimetry (WG7).

Venue

Karlsruhe Institute of Technology (KIT)
Campus North
Hermann-von-Helmholtz-Platz 1
76344 Eggenstein-Leopoldshafen

For information on travel and accomodation see the webpage of the course
http://eurados.ine.kit.edu

Prerequisites

The Monte Carlo code used throughout the course will be MCNP(X). Thus all participants are required to have at least a basic knowledge of MCNP(X). The number of participants is limited to 20. Participants should bring their own laptops and if possible a licensed copy of MCNP(X). Participants are invited to bring a poster presenting their own laboratory and work.

Registration

Deadline for registration is **September 15th, 2013**. A Registration Form is provided at the course webpage: **http://eurados.ine.kit.edu**

KIT and EURADOS will confirm your participation after the registration deadline. Upon confirmation you will receive the invoice for the participation fee. Deadline for payment is October 25th 2013.

Registration fees

Regular Fee: 550 €

Reduced Fee: 500 €
Applies for participants from the EURADOS Sponsoring Institutions (see http://www.eurados.org/en/Sponsors)

Students Fee: 350€ Students
Applies for students which are registered at a university. (A proof of matriculation needs to be presented at registration)

All fees are exclusive VAT. 7% VAT will be added for invoices to participants from Germany and from EU member states who cannot provide us with their VAT-ID number.

The fees will cover coffee breaks, a social dinner and all course materials (printed and digital form)

Contact: bastian.breustedt@kit.edu, debora.leone@kit.edu

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http://eurados.ine.kit.edu

Training Course Format

Short introdcutory lectures will summarize the basics of in-vivo counting, Monte Carlo Methods and Voxel models. The biggest part of the course will be hands-on-training, centered on an exercise in KIT's in-vivo lab. Based on a „case study" the exercise will guide the participants step by step through a Monte Carlo calibration of an in-vivo counter using voxel phantoms. Lecturers and tutors will be known experts on Monte Carlo methods and in-vivo monitoring from European Institutions collaborating in EURADOS working groups on computational (WG6) and internal dosimetry (WG7). Course material will be provided in printed and digital form at the course. The Monte Carlo code used throughout the course will be MCNP(X). Thus all participants are required to have at least a basic knowledge of MCNP(X). For the exercise part of the course you should bring a laptop with a licensed copy of MCNP(X) to work on this. Alternatively participants may work in groups.

Time	Monday	Tuesday	Wednesday
08:30 – 10:00 h	Monte-Carlo and in-vivo Counting (Introductory Lecture)	Modeling of Detectors	Monte Carlo Calibration
10:00 – 10:30 h	Coffee Break		
10:30 – 12:00 h	Voxel Models (Introductory lecture) + Outline of Exercise	Modeling of Phantoms	Monte Carlo Calibration
12:00 – 13:00 h	Lunch Break		
13:00 – 14:30 h	Modeling of Detectors	Modeling of Phantoms	Application to „Case Study"
14:30 – 16:00 h	Modeling of Detectors	Modeling of Phantoms	Final discussion and Course Wrap-up
16:00 – 16:30 h	Coffee Break		
16:30 – 18:00 h	Poster Session of Participants	Modeling of Phantoms	Adjourn
19:30 h -		Social Event	

Outline of the Training Course

Organizers

EURADOS – http://www.eurados.org

We are a network of more than 50 European institutions (Voting Members) and 200 scientists (Associate Members). As a non-profit organization we promote research and development and European cooperation in the field of the dosimetry of ionizing radiation. We maintain a network which includes experts, reference and research laboratories, and dosimetry services. Our activities encompasses the coordination of working groups which promote technical development and its implementation in routine work. WGs also contribute to compatibility within Europe and conformance with international practices. EURADOS organizes scientific meetings, training activities, intercomparisons and bench mark studies.

KIT - http://www.kit.edu

On October 01, 2009, the Karlsruhe Institute of Technology (KIT) was founded by a merger of Forschungszentrum Karlsruhe (FZK) and Universität Karlsruhe. KIT bundles the missions of both precursory institutions: A university of the state of Baden-Wuerttemberg with teaching and research tasks and a large-scale research institution of the Helmholtz Association conducting program-oriented provident research on behalf of the Federal Republic of Germany. Within these missions, KIT is operating along the three strategic fields of action of research, teaching, and innovation.

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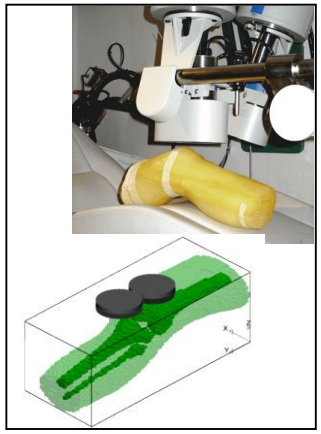
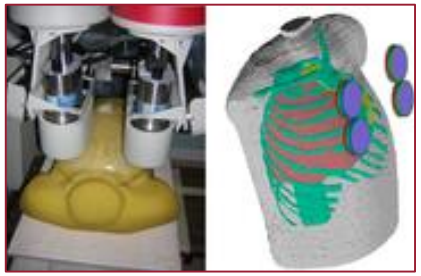
KIT – University of the State of Baden-Wuerttemberg and
National Research Center of the Helmholtz Association

Previous EURADOS MC intercomparisons in vivo monitoring of incorporated radionuclides

(1) *Monte Carlo modelling of Germanium detectors for the measurement of low energy photons in internal dosimetry: results of an international comparison".* J.M. Gómez-Ros et al. ***Radiation Measurements 43 pp 510-515 (2006)***



(2) *Monte Carlo modelling for the* ***in vivo lung monitoring of enriched uranium:*** *Results of an international comparison ".* D. Broggio et al. ***Radiation Measurements 47 pp 492-500 (2012)***



(3) *Measurements and Monte Carlo modeling for the assessment of americium in a USTUR leg phantom*

EURADOS and USTUR Collaboration

M.A. Lopez et al. ***Radiation Protection Dosimetry Vol 114, No1-4 pp 295-299 (2011)***