

The IAEA BSS and development of an international dosimetry protocol

MetroMRT 3rd Workshop

National Physical Laboratory, Teddington, UK
20-21 April 2015

Gian Luca POLI

International Atomic Energy Agency
Dosimetry and Medical Radiation Physics section



IAEA

International Atomic Energy Agency

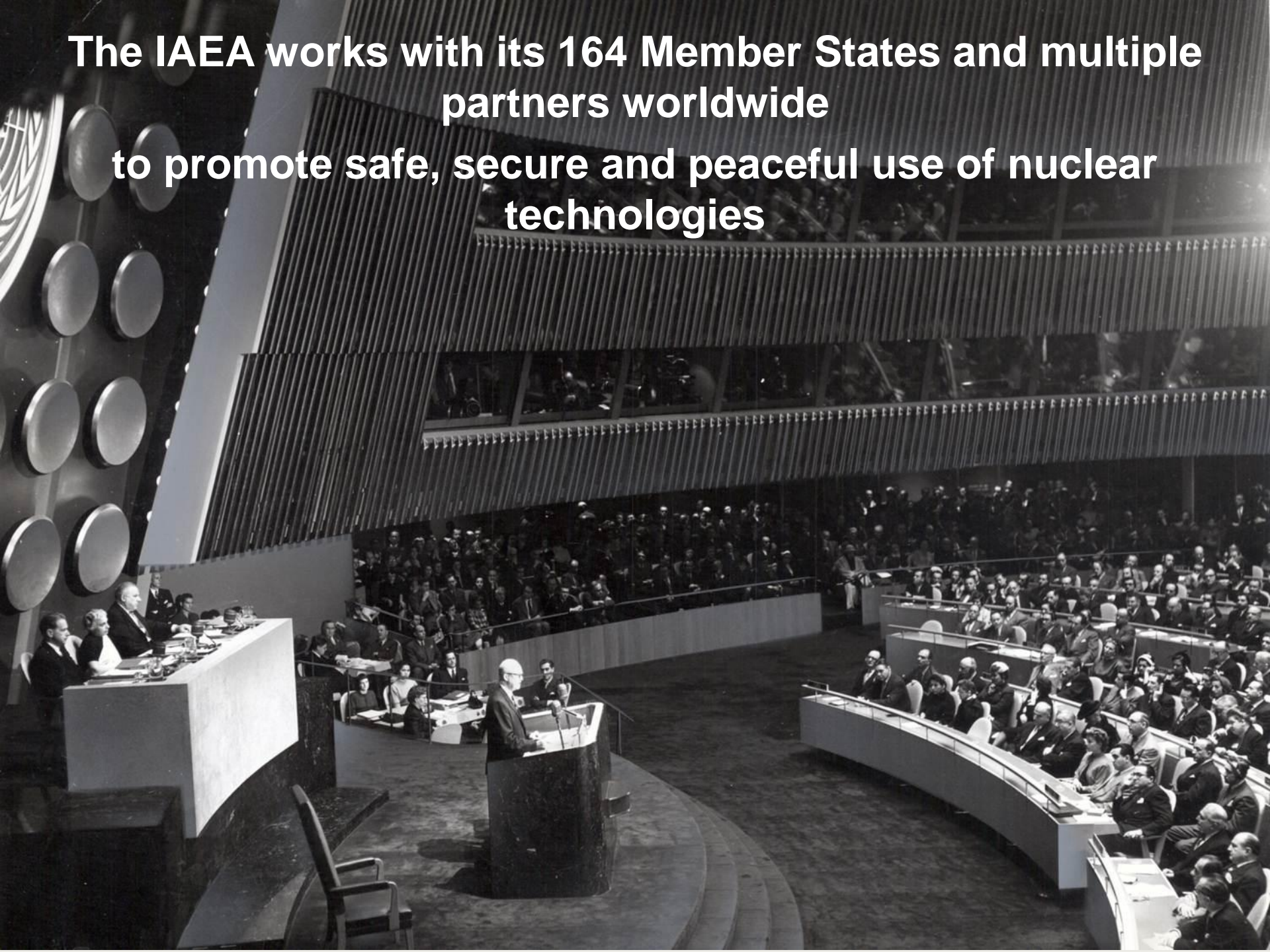
Outline

- ✓ IAEA support to Nuclear Medicine Medical Physics
- ✓ The International Basic Safety Standard
- ✓ Human Health Report n. 9 on Quantitative Nuclear Medicine Imaging
- ✓ Coordinated Research Project on Quantitative Nuclear Medicine Imaging
- ✓ Need for an international dosimetry protocol

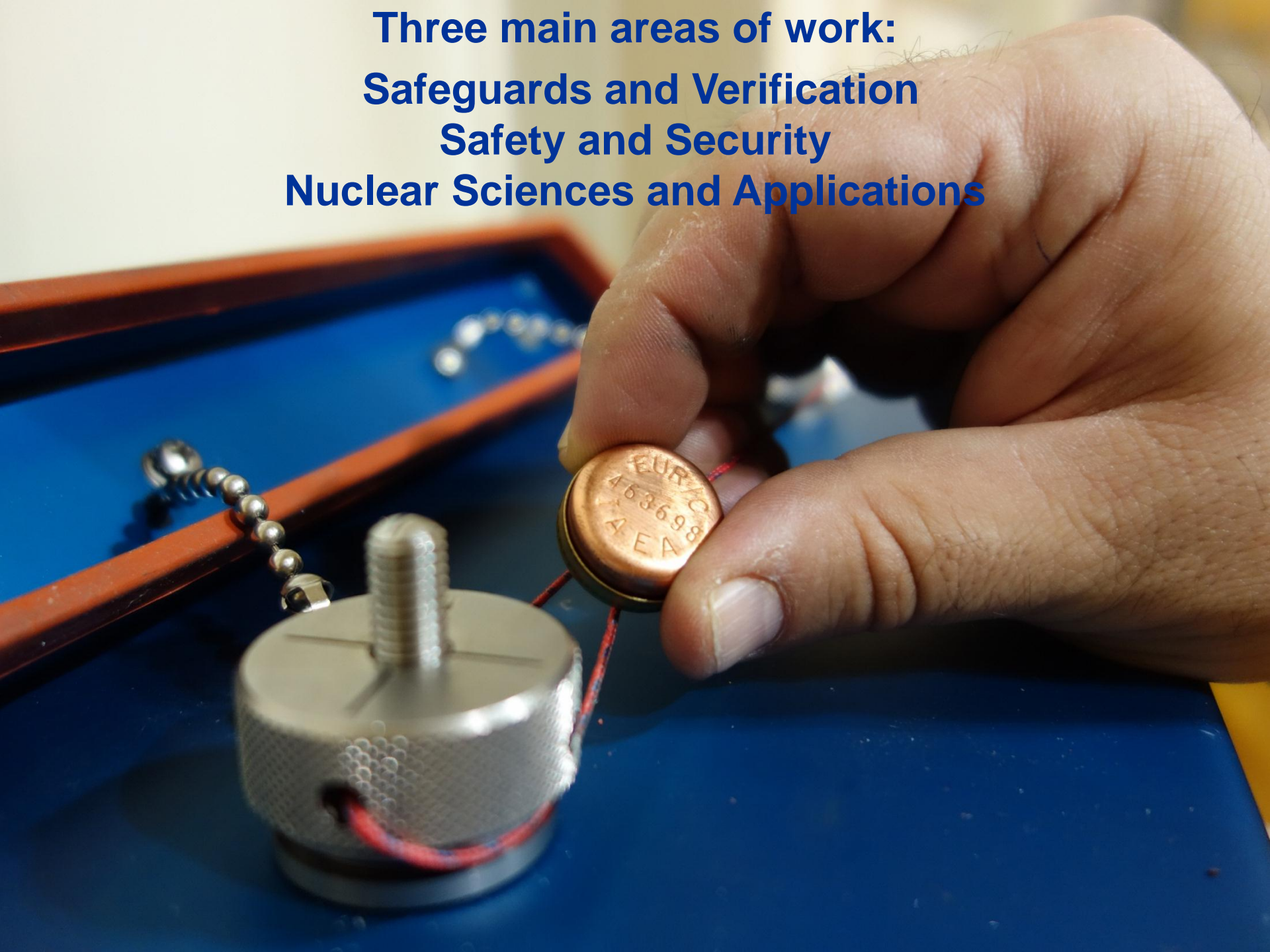
A low-angle, upward-looking photograph of the International Atomic Energy Agency (IAEA) building. The building's facade is a large, curved, grid-like structure of windows, reflecting the sky. In the foreground, several national flags are flying on tall poles. The sky is a clear, deep blue. A semi-transparent dark blue banner is overlaid across the middle of the image, containing white text.

The IAEA is an independent organization within the United Nations serving as the global focal point for nuclear cooperation worldwide


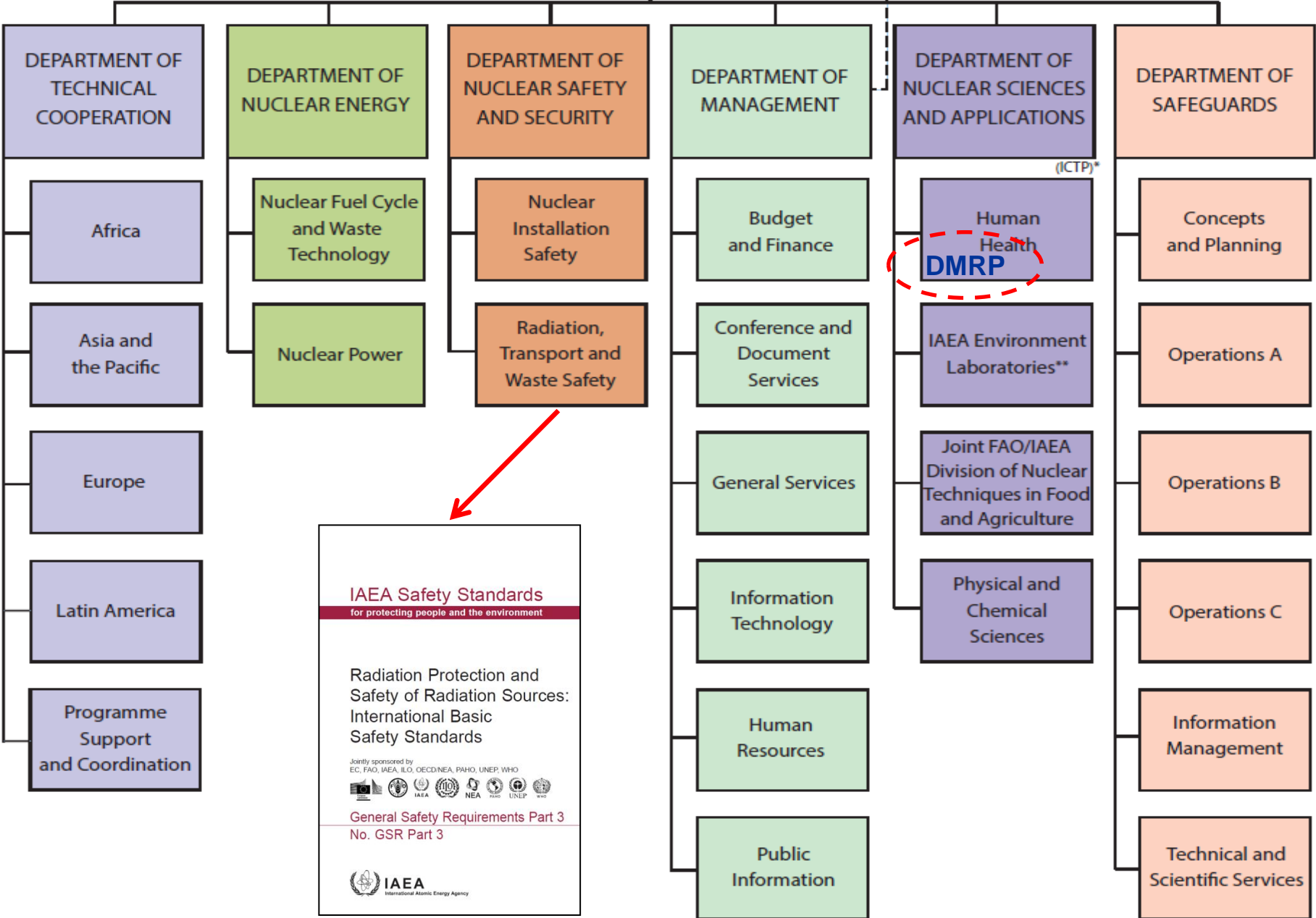
The IAEA works with its 164 Member States and multiple partners worldwide to promote safe, secure and peaceful use of nuclear technologies



Three main areas of work:
Safeguards and Verification
Safety and Security
Nuclear Sciences and Applications




DIRECTOR GENERAL
Mr Yukiya Amano


IAEA Safety Standards
for protecting people and the environment

Radiation Protection and Safety of Radiation Sources:
International Basic Safety Standards

Jointly sponsored by
EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO



General Safety Requirements Part 3
No. GSR Part 3



IAEA Human Health Division

Dep. of Nuclear Sciences and Applications

Human Health

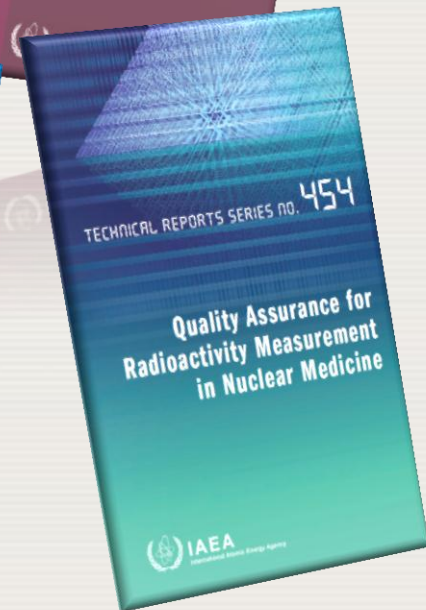
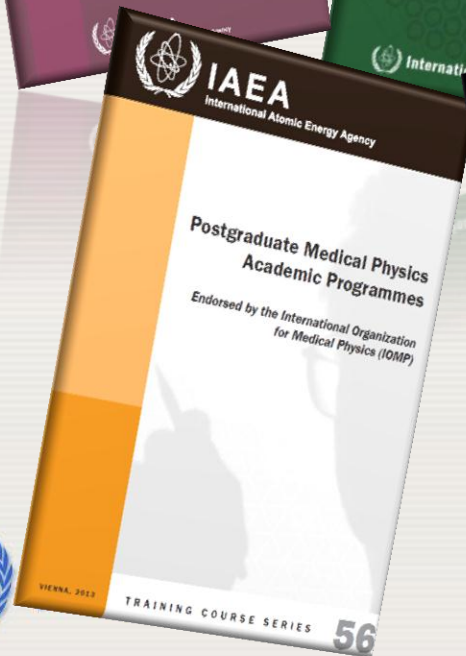
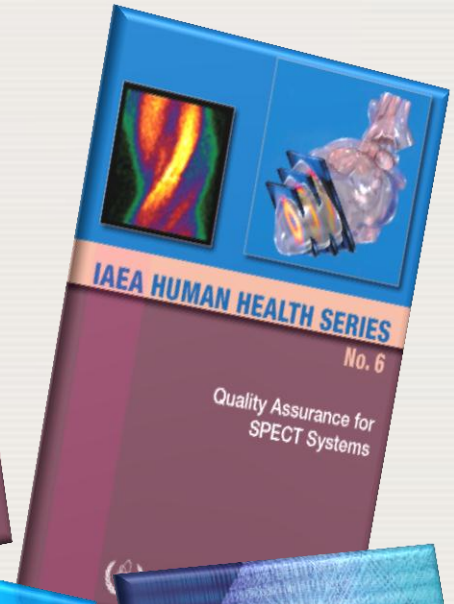
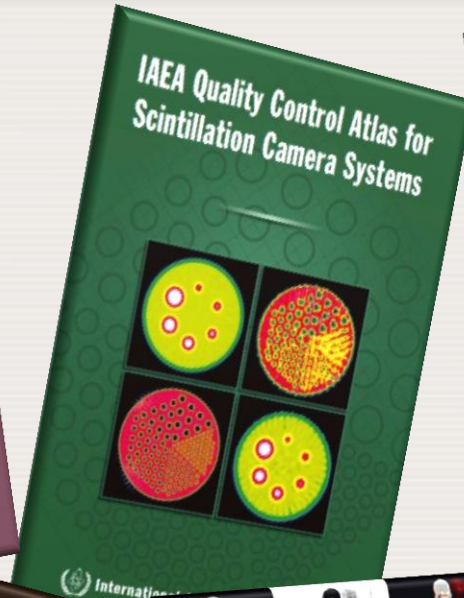
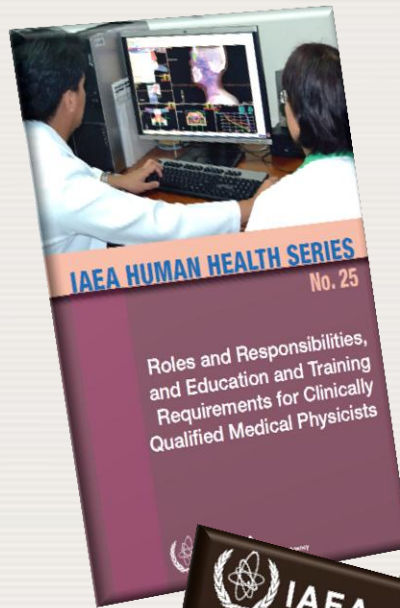
**Nuclear Medicine
and Diagnostic Imaging**

**Applied Radiation Biology
and Radiotherapy**

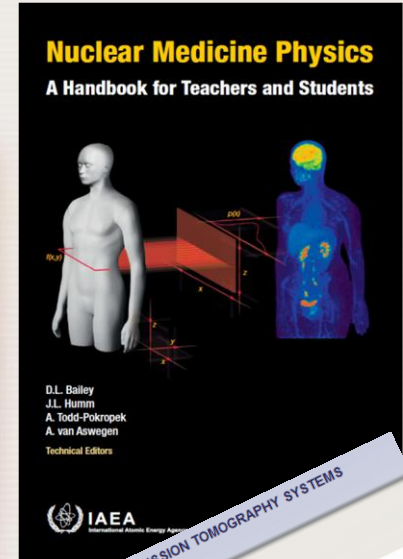
**Dosimetry and Medical
Radiation Physics (DMRP)**

**Nutritional and Health-Related
Environmental Studies**

Development of guidelines

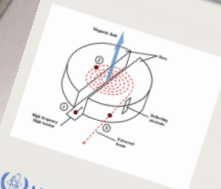


Education & Training



4.3 ACCELERATOR PRODUCTION
4.3.1 Cyclotron, principles

11.3 POSITRON EMISSION TOMOGRAPHY SYSTEMS
11.3.4 Data acquisition
11.3.4.4 Time of flight (TOF)

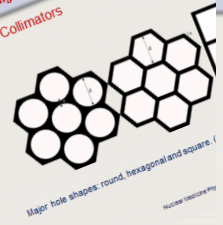


TOF PET
With time of flight PET, the time difference between the signals recorded at detectors A and B is used to estimate the position of the annihilation event along the line of response.

An annihilation event in a gap, while the charge to a detector.

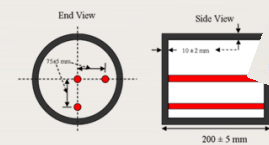


11.2 GAMMA CAMERA SYSTEMS
11.2.2 The Anger camera
11.2.2.1 Collimators



15.2 HARDWARE
15.2.2 SPECT phantoms

15.2.2.2 Triple-line source phantom for SPECT



Schematic drawing of the side and front views of a triple-line source phantom

15.3 COMPUTATIONAL MODELS

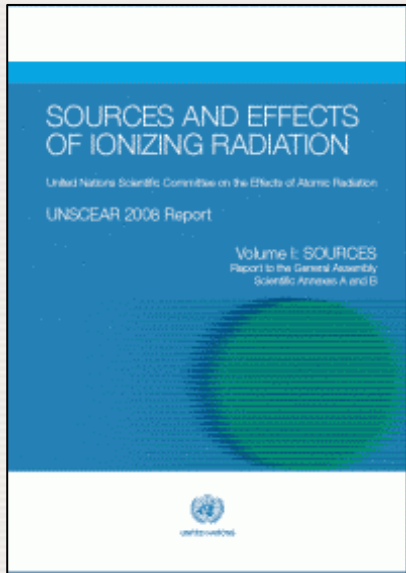


Left: initial extension of the 4-D XCAT anatomy; right: simulated chest X-ray CT images reconstructed from the extended 4-D XCAT. Coronal (top row) and trans axial (bottom two rows) reconstructed slices are shown (reproduced with permission from P. Segars).

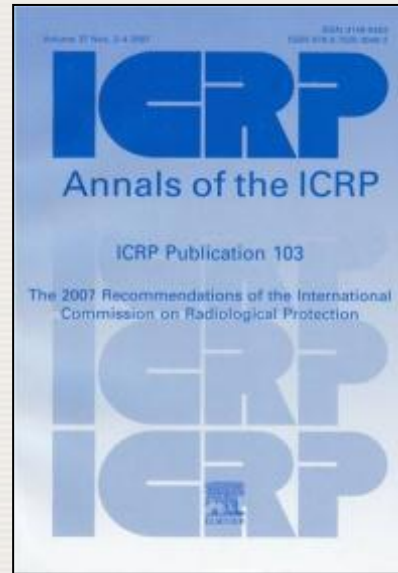
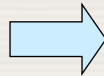
Technical Cooperation



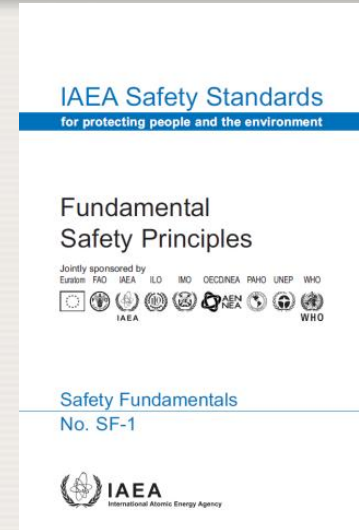
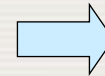
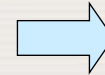
The International Basic Safety Standard



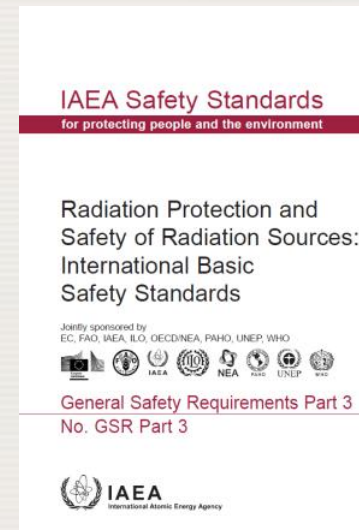
UNSCEAR studies effects of atomic radiation



ICRP provides recommendations for protection



Essential principles
(moral obligation)



Essential requirements
(legal obligation)

IAEA Safety Standards hierarchy

Safety Fundamentals



Fundamental safety objectives and principles for protecting people and environment
moral obligation

Safety Requirements



Requirements that must be met to ensure safety
legal obligations, "shall"

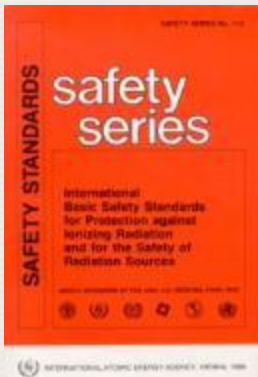
Safety Guides



Recommended ways of meeting the requirements,
"should"

International BSS

1996



→ Review
2005 - 2006

→ Revision
2007- 2011

IAEA and other
cosponsors:
FAO, ILO, NEA/OECD,
PAHO, UNEP, WHO, EC

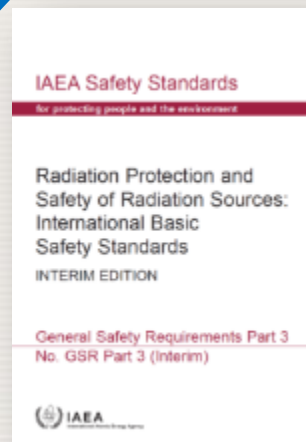
→ IAEA approval
2011

→ Cosponsor approval

EC, FAO, IAEA, ILO, OECD/NEA, PAHO, UNEP, WHO

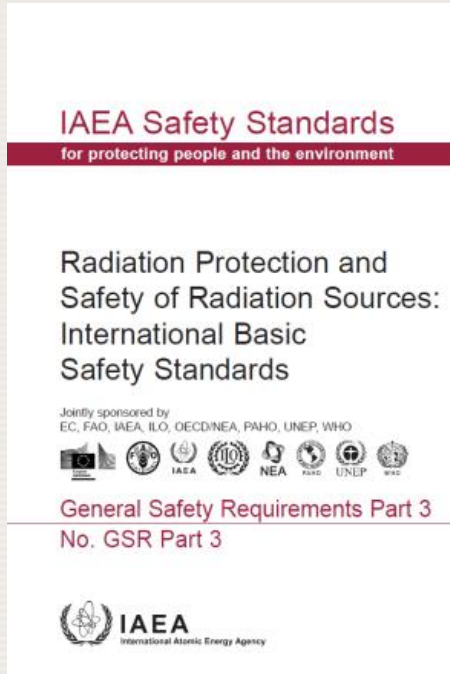


IAEA Member
States



→ Published
July 2014

International BSS



- Not mandatory
 - No obligation for States to bring legislation into conformity, etc.
- However
 - Used as a template for many national regulations
 - **Mandatory for Member States receiving technical assistance from IAEA**
 - **The IAEA must use the Standards in its own operations**



July 2014



International BSS

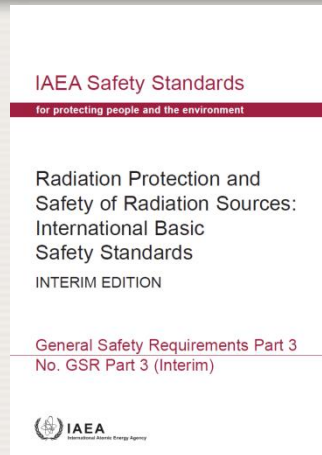
3.165 - For therapeutic radiological procedures in which radiopharmaceuticals are administered, the radiological medical practitioner, in cooperation with the medical physicist and the medical radiation technologist, and if appropriate with the radiopharmacist or radiochemist, shall ensure that for each patient the appropriate radiopharmaceutical with the appropriate activity is selected and administered so that the radioactivity is primarily localized in the organ(s) of interest, while the radioactivity in the rest of the body is kept as low as reasonably achievable.

International BSS

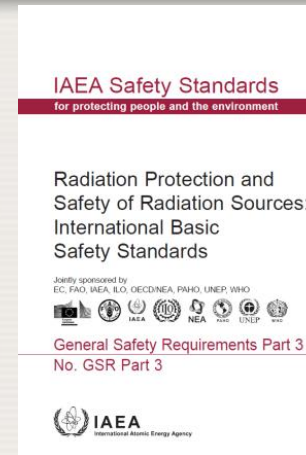
Dosimetry of patients

3.167. Registrants and licensees shall ensure that dosimetry of patients is performed and documented by or under the supervision of a **medical physicist**, using calibrated dosimeters and following **internationally accepted or nationally accepted protocols**, including dosimetry to determine the following:

Dosimetry of patients



Nov
2011



July
2014

...

(c) For therapeutic medical exposures, absorbed doses to the tissues or organs for individual patients, as determined to be relevant by the radiological medical practitioner.

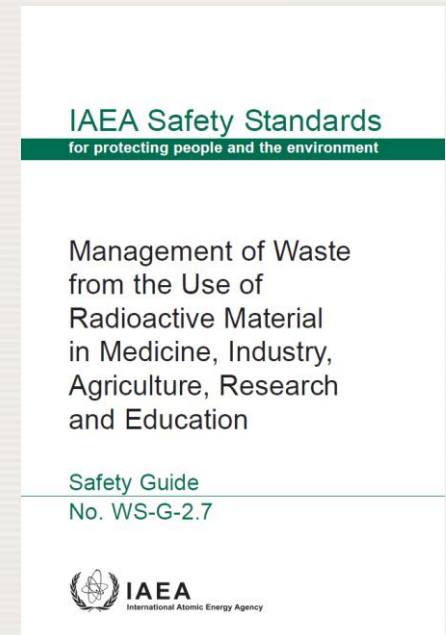
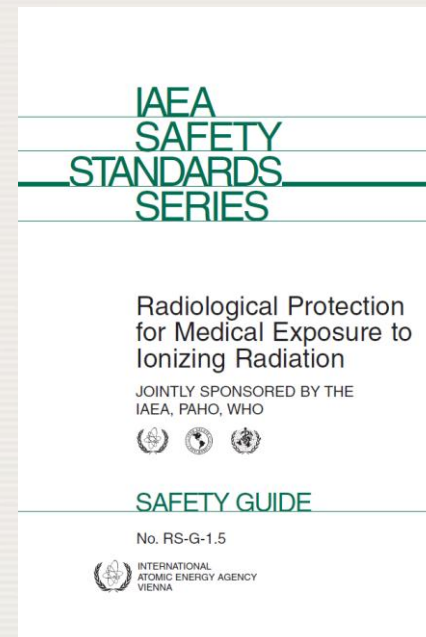
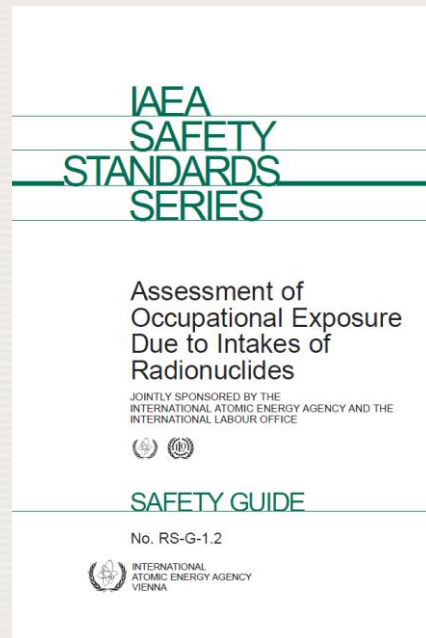
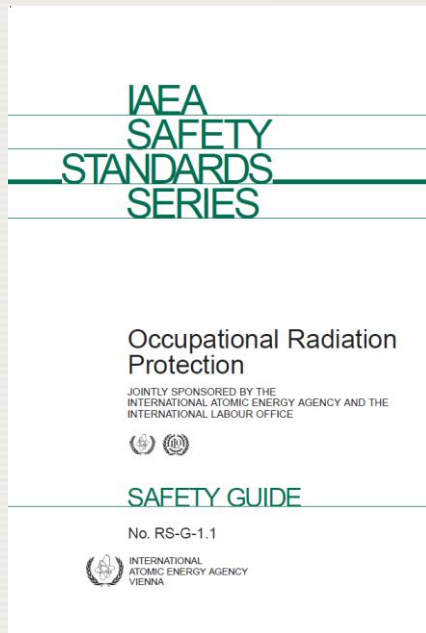
...

(c) For therapeutic radiological procedures, absorbed doses to the planning target volume for each patient treated with external beam therapy and/or brachytherapy and absorbed doses to relevant tissues or organs as determined by the radiological medical practitioner;

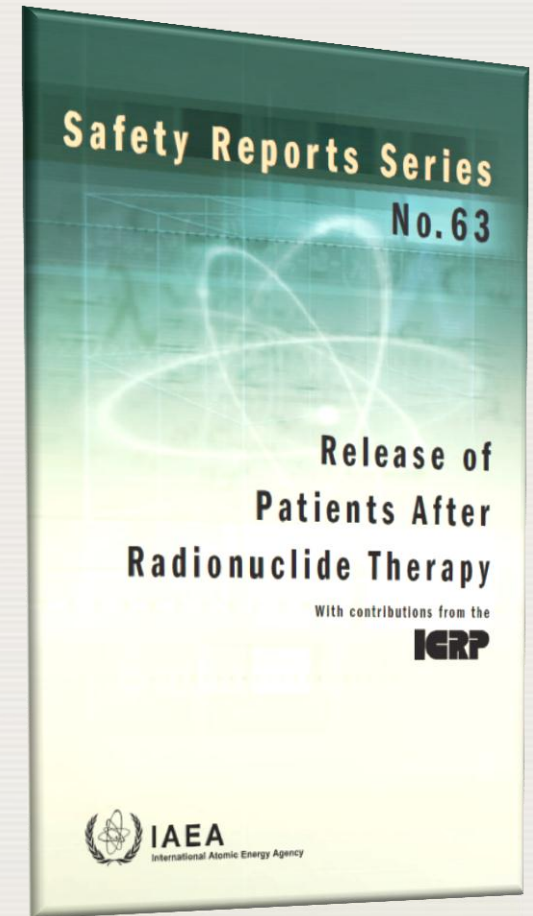
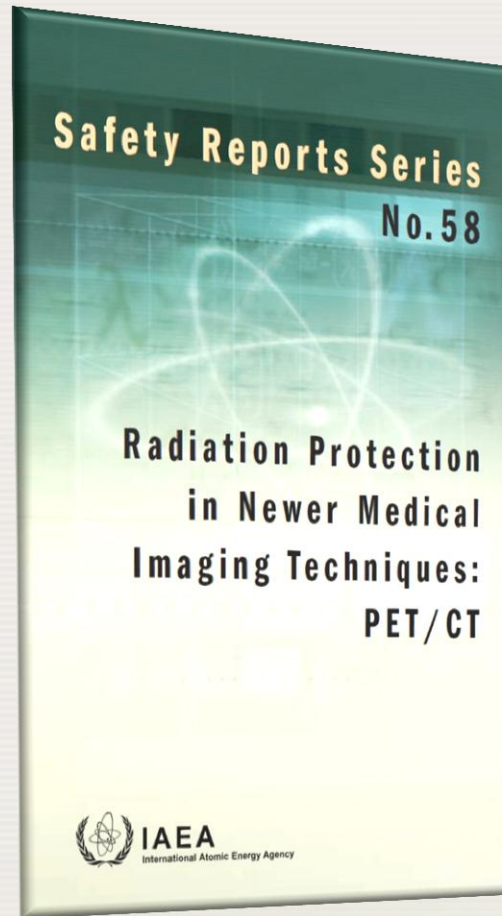
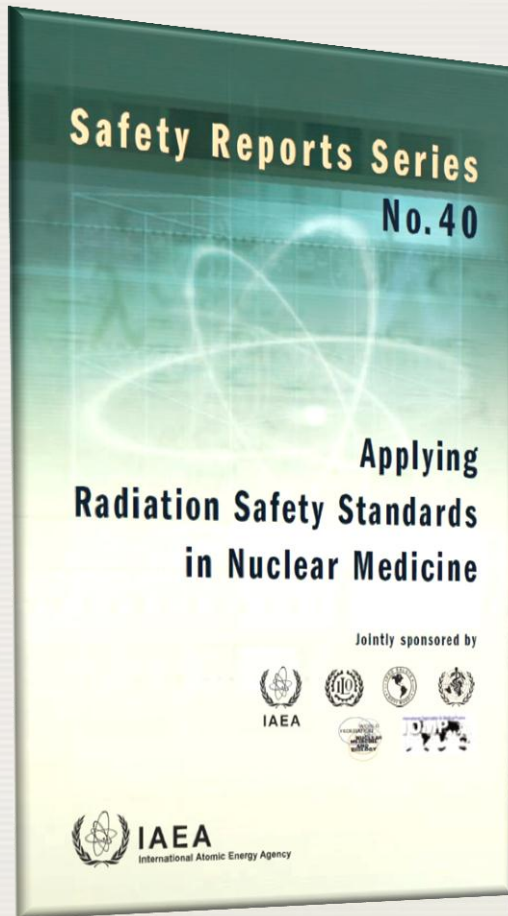
(d) For therapeutic radiological procedures with unsealed sources, typical absorbed doses to patients.

Safety Guides

- Recommended ways of meeting the requirements
- “should” statements



Safety Reports



Safety Guide on Medical Uses

IAEA Safety Standards

for protecting people and the environment

Safety Guide on Radiation Protection and Safety in Medical Uses of Ionizing Radiation

Specific Safety Guide

No.



IAEA
International Atomic Energy Agency

IAEA
SAFETY
STANDARDS
SERIES

Radiological Protection
for Medical Exposure to
Ionizing Radiation

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IAEA, WHO, WHO



SAFETY GUIDE

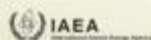
No. RS-G-1.5



Safety Reports Series
No. 38

Applying
Radiation Safety Standards
in Radiotherapy

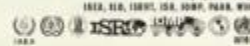
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Safety Reports Series
No. 39

Applying
Radiation Safety Standards
in Diagnostic Radiology
and Interventional
Procedures Using X Rays

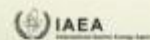
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Safety Reports Series
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Applying
Radiation Safety Standards
in Nuclear Medicine

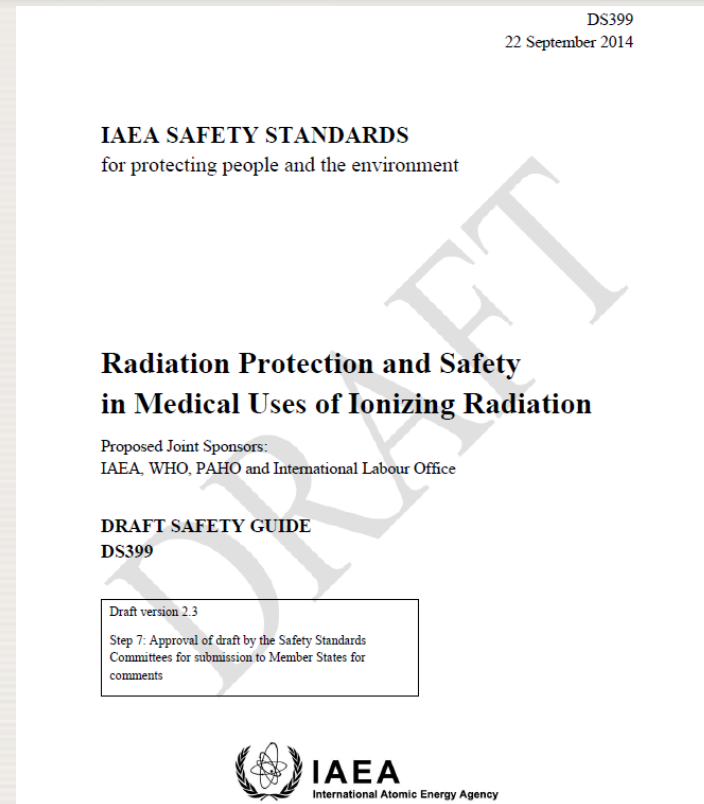
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Safety Guide on Medical Uses

- ✓ Medical exposure
- ✓ Occupational exposure
- ✓ Public exposure

- ✓ Radiation therapy
- ✓ Diagnostic radiology and image guided interventional procedures
- ✓ Nuclear medicine



Dosimetry of patients – radiopharmaceutical therapy procedures

4.209. The BSS paragraph 3.168 requires nuclear medicine facilities to determine typical absorbed doses to patients for their therapeutic radiological procedures. As in para. 4.208, methodologies for the determination of doses from therapy radiopharmaceuticals are explained in detail in Refs [249, 251, 257, 258, 272 – 278].

Quantitative Nuclear Medicine Imaging

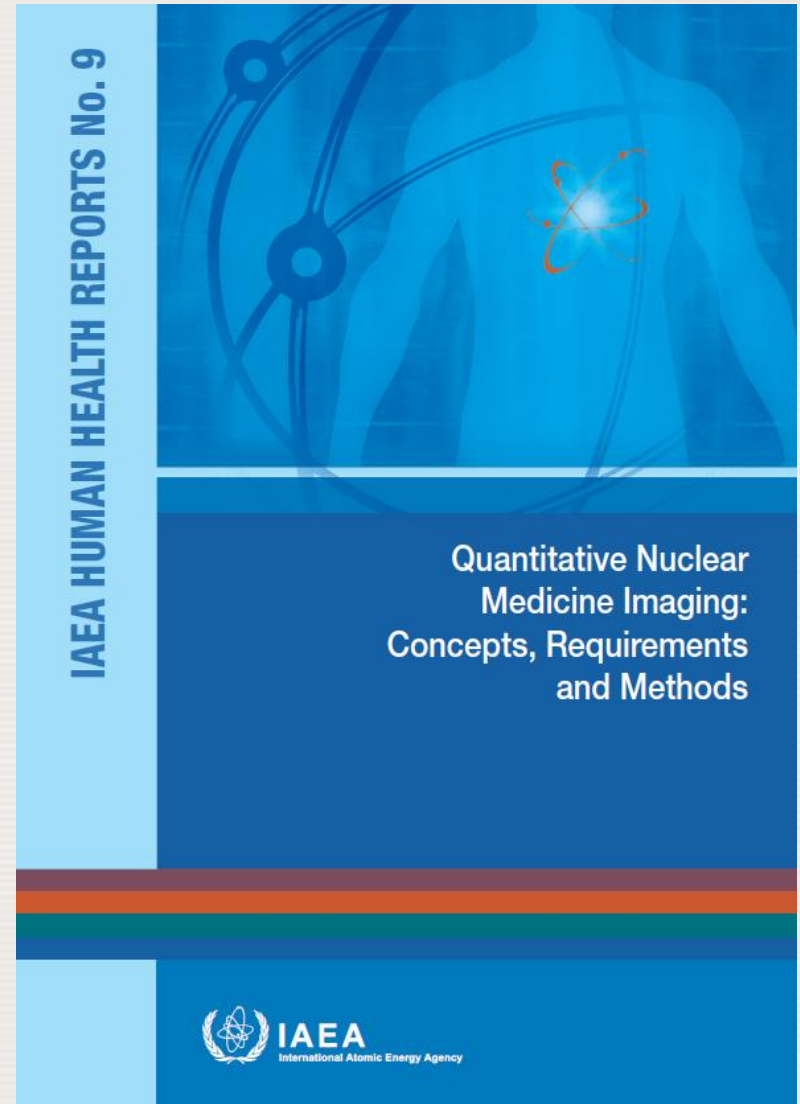
Procedures for
**quantification of
nuclear medicine
images** and for internal
dosimetry

I. Buvat

E. Frey

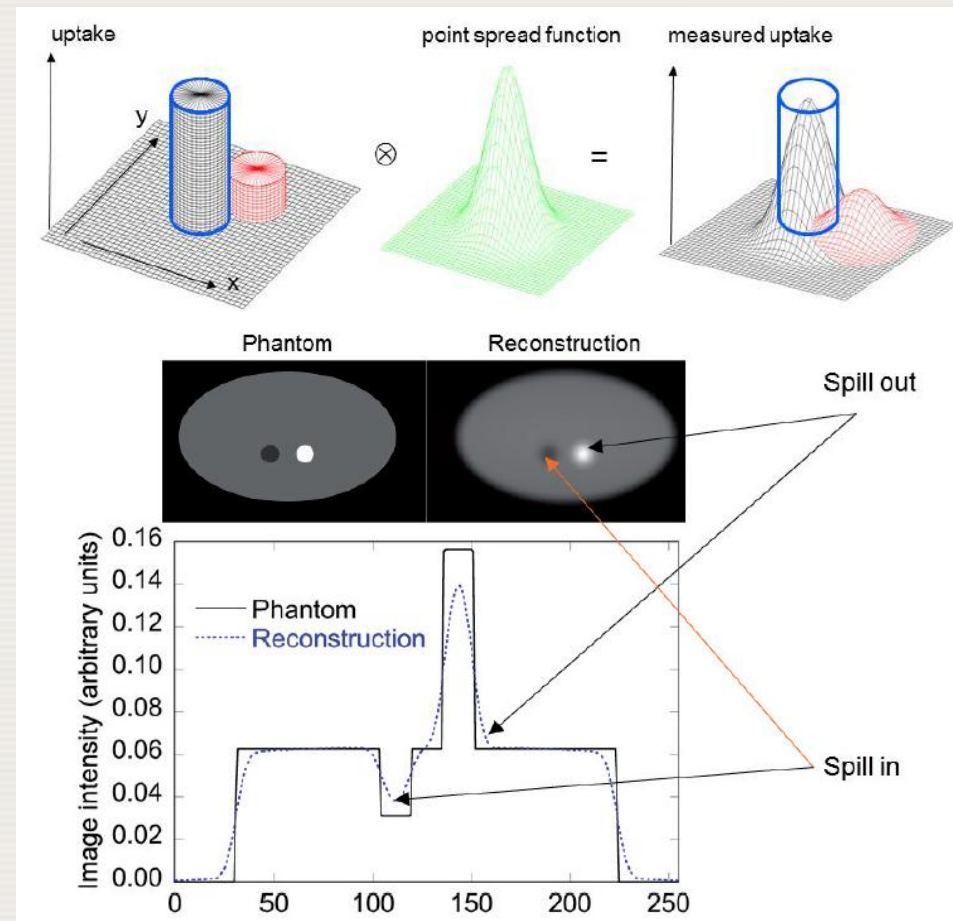
A. Green

M. Ljungberg



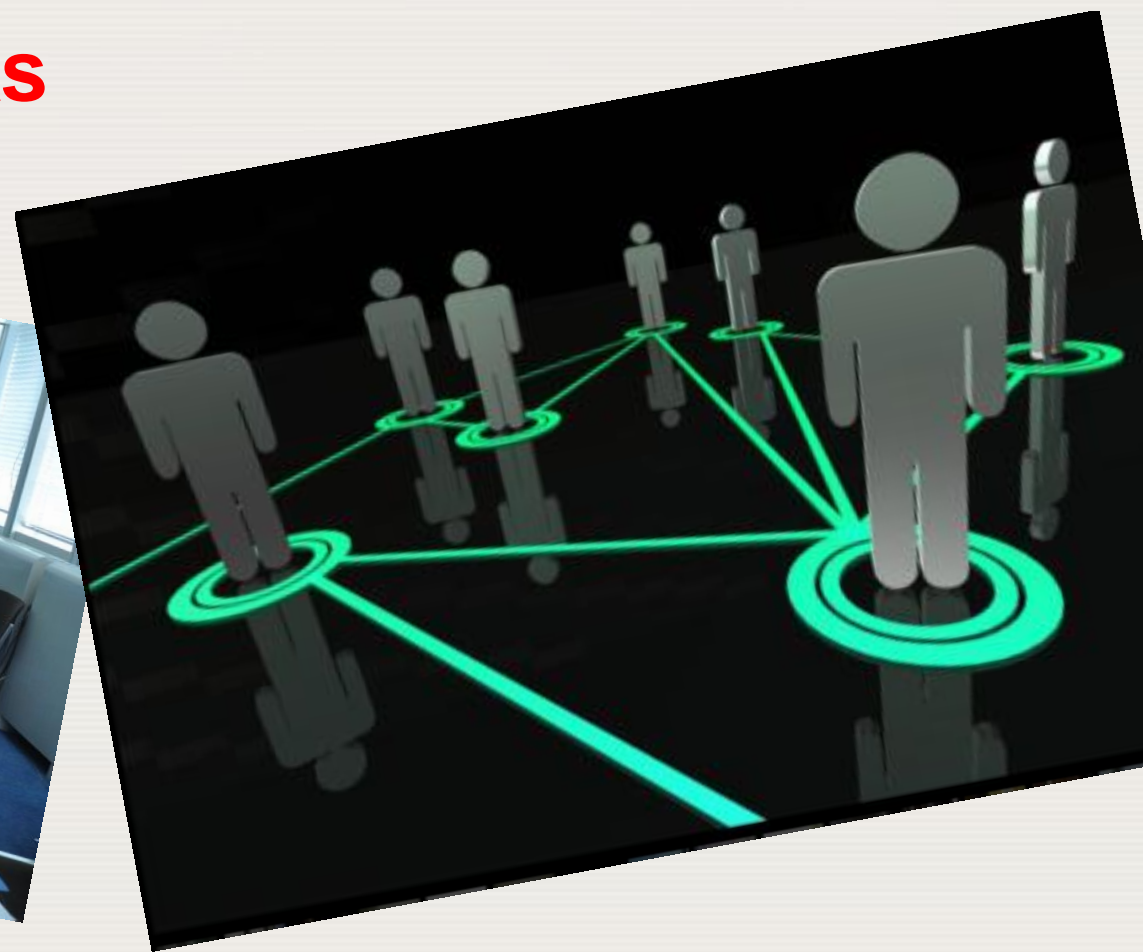
Quantitative Nuclear Medicine Imaging

- ❑ Physical effects that degrade image quality and affect the accuracy of quantification
- ❑ Methods to compensate for them in
 - ✓ Planar
 - ✓ SPECT
 - ✓ PET



Coordinated Research Projects

Involve participants from different countries into state of the art **scientific research** and create **scientific networks**



Coordinated Research Projects

CRP “Development of Quantitative Nuclear Medicine Imaging for Patient Specific Dosimetry”

Purpose:

- ✓ investigate **image quantification** capabilities
- ✓ assess the need for **training**
- ✓ assess the need for **standardisation**
- ✓ assess the typical **accuracy**

Participants

- Bangladesh
- Brazil
- Croatia
- Cuba
- Germany
- South Africa
- Sweden
- Thailand
- United Kingdom
- USA
- Uruguay

Trained medical physicist with experience in quantitative imaging

Scanners:

- ✓ Siemens E.Cam (1)
- ✓ Mediso Nucline (2)

} SPECT

- ✓ Siemens Symbia (5)
- ✓ GE Infinia Hawkeye-4 (1)
- ✓ GE Discovery 670 (2)

} SPECT/CT

^{133}Ba intercomparison

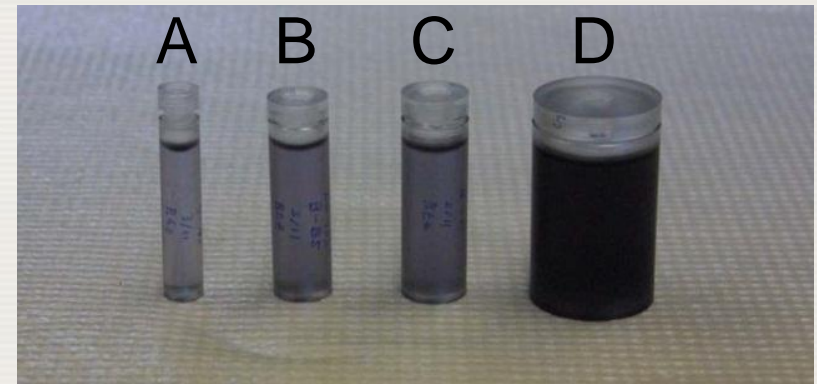
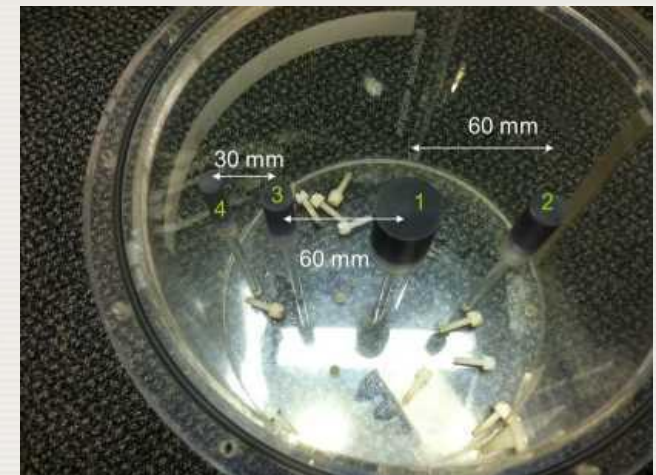
- ✓ Guidance document
- ✓ ^{133}Ba sources production
- ✓ Image sources in filled Jaszczak phantom
 - *Trial 1: determine activity with local protocol*
- ✓ Analyse results of Trial 1
- ✓ New guidelines and harmonized protocol
 - *Trial 2: use new guidelines and protocol*
- ✓ Comparison of Trial 1 vs Trial 2
 - *Centralized data analysis*

^{133}Ba sources

Sources produced by NIST:

- ^{133}Ba (356 keV) as a surrogate for ^{131}I
- Standard uncertainty <1.7%
- Height: 4 cm

Source	ϕ_{internal} (cm)	V (cm ³)
A	0.794	2
B	1.27	4
C	1.43	6
D	2.86	23



Common errors and critical aspects

- TEW energy windows settings

PLANAR

- Methods that would not translate well clinically (e.g., used known phantom geometry)
- ROI definition
- Attenuation coefficient
- Transmission study

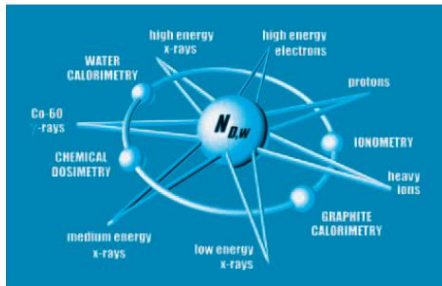
SPECT w/Chang-AC

- Boundaries definition in Chang's AC method
- Apply Chang

Conclusions

- Planar: good results with a simple geometry
- Chang's method for attenuation correction is critical
- SPECT/CT is more standardized and less subject to errors
- Reliable quantification of activity is feasible but requires attention to details
- Need for training
- Need for harmonized protocols

Technical Reports



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An International Code of Practice for Dosimetry
Based on Standards of Absorbed Dose to Water

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INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2000

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**Dosimetry in Diagnostic
Radiology: An International
Code of Practice**



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TECHNICAL REPORTS SERIES NO. **454**

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Radioactivity Measurement
in Nuclear Medicine**



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International Atomic Energy Agency

Thank you

