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Internal Dosimetry in Occupational Radiation Protection – The TECHREC project

EURADOS Annual Meeting AM2017

Winter School "Internal dosimetry for radiation protection and medicine"

2 March 2017, KIT, Karlsruhe, Germany

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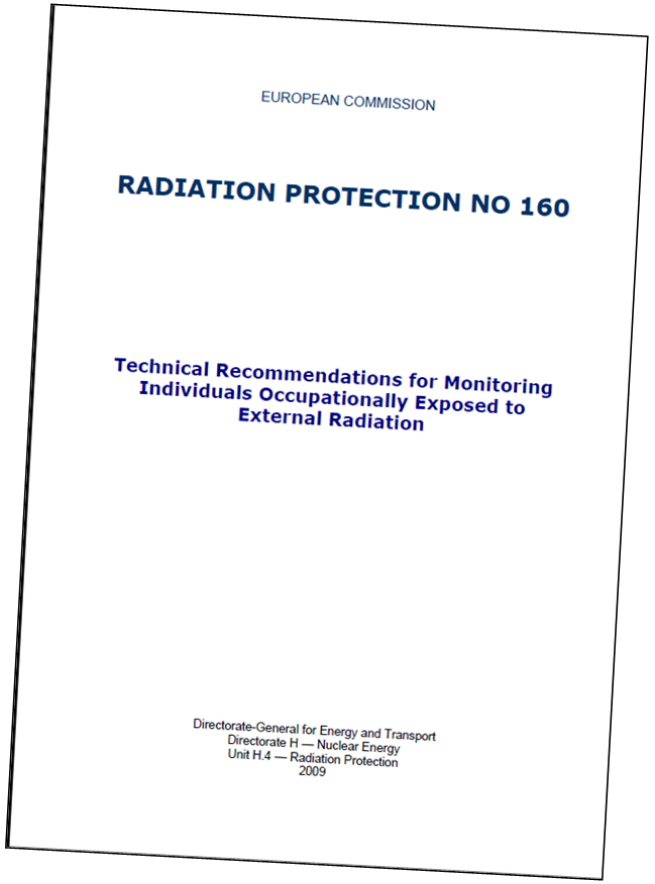
History of the project

2009 – *Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation*, developed by EURADOS, published as European Commission Report RP160

2010 – EURADOS proposes development of a complementary report on:
Technical Recommendations for Monitoring Individuals for Occupational Intakes of Radionuclides

2014 – TECHREC project commences (completion on **11 May 2016**)


EUROPEAN COMMISSION

RADIATION PROTECTION NO 160

Technical Recommendations for Monitoring Individuals Occupationally Exposed to External Radiation

Directorate-General for Energy and Transport
Directorate H — Nuclear Energy
Unit H.4 — Radiation Protection
2009

EURADOS – European Radiation Dosimetry Group
www.eurados.org

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Aim of the project

To provide a report that gives:

a. a complete account of the **principles** of monitoring for intakes of radionuclides;

b. comprehensive, detailed, authoritative and internally-consistent guidance on the **practice** of individual monitoring and internal dosimetry

- taking account of all recent developments

Target audience:

- dosimetry services
- competent national & international authorities
- site operators with responsibilities for radiation protection programmes
- radiation protection experts
- equipment manufacturers
- laboratories providing bioassay services
- government bodies aiming to harmonise regulations and guidance

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Why is the report needed now?

***Expertise**:* There is a current need to pass on expertise to younger scientists

Literature: There is currently no single document that presents a complete account of the principles and practice of internal dose assessment

Consensus: … is needed on a number of practical issues

***Legislative environment**:* **Council Directive 2013/59/Euratom** will be implemented in national legislation by 6 February 2018. Recommendations on translating internal dosimetry principles into practice are needed.

***Scientific environment**:* Publication of ICRP's **Occupational Intakes of Radionuclides** report series is on-going. Recommendations based on the latest scientific developments are needed.

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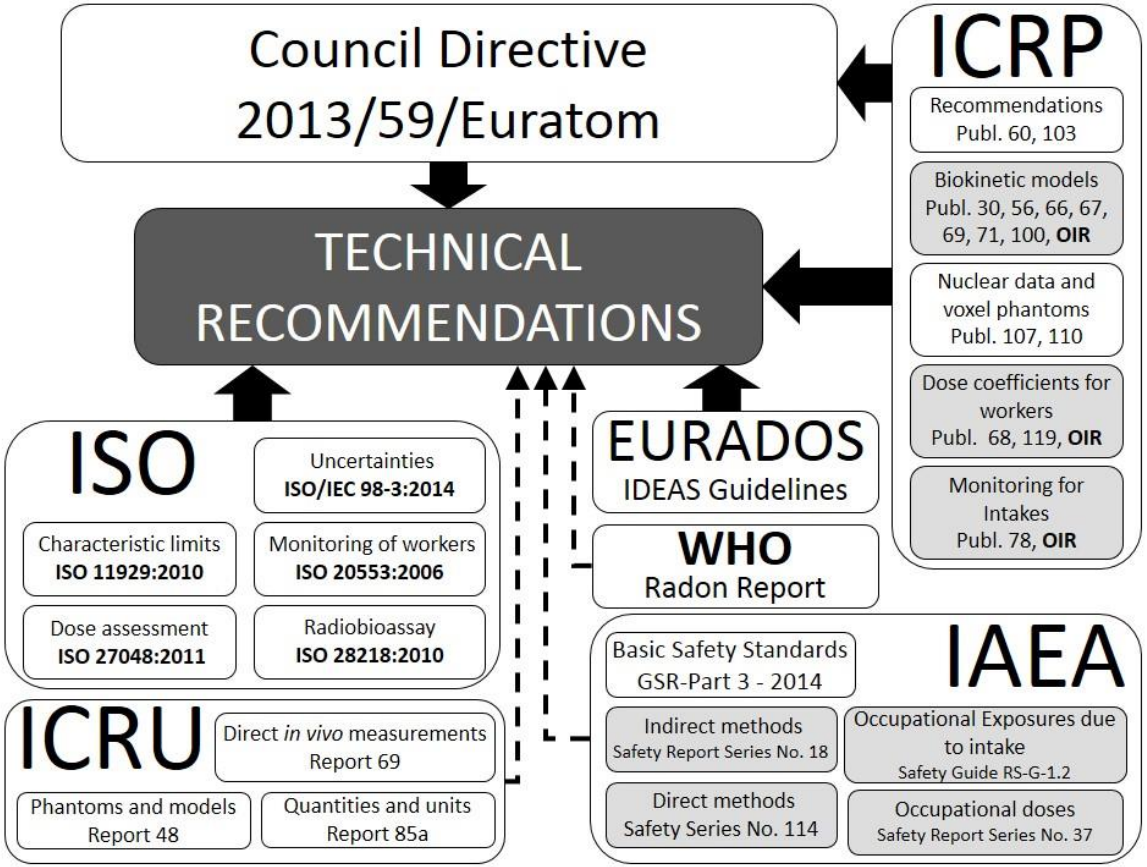
Sources of information

Documents currently being revised are lightly-shaded



OIR: ICRP's Occupational Intakes of Radionuclides (OIR) Report Series

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Sources of information – ISO and EURADOS

A. ISO 20553:2006. Monitoring of workers occupationally exposed to a risk of internal contamination with radioactive material

B. ISO 28218:2010. Performance criteria for radio-bioassay

C. ISO 27048:2011. Dose assessment for the monitoring of workers for internal radiation exposure

D. ISO 16638-1:2015. Monitoring and internal dosimetry for specific materials. Part 1: Uranium

E. C.M. Castellani, J.W. Marsh, C. Hurtgen, E. Blanchardon, P. Bérard, A. Giussani, M.A. Lopez (2013). IDEAS Guidelines (Version 2) for the Estimation of Committed Doses from Incorporation Monitoring Data. EURADOS Report 2013-01

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Structure of the report chapters

Each Chapter presents:

- A single main “question” that is addressed by the chapter
- A set of subsidiary, more specific questions
- “Special Terms” used in the Chapter
- Introduction
- Technical and scientific discussion
- *Recommendations* that give specific responses to each question

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Technical Recommendations - Chapters

A. Purpose, Context, Scope; Implementation by Internal Dosimetry Services (5 Recommendations)

B. General Principles

C. Monitoring Programmes (19 Recommendations)

D. Methods of Individual and Workplace Monitoring (39 Recommendations)

E. Routine and Special Dose Assessment (+ Special Topics) (29 Recommendations)

F. Accuracy Requirements and Uncertainty Analysis (8 Recommendations)

G. Quality Assurance and Criteria for Approval & Accreditation (14 Recommendations)

H. Radon Measurement and Dosimetry for Workers (15 Recommendations)

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Technical Recommendations - Annexes

I. Reference Biokinetic and Dosimetric Models

II. Examples of Monitoring Programme Design and Internal Dose Assessment

III. Monitoring and Internal Dosimetry for First Responders in a Major Accident at a Nuclear Facility

IV. Internal Dosimetry for Assessment of Risk to Health

V. Compilation of the Recommendations

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Recommendations are graded
M – Mandatory (e.g. EURATOM Directive)
I – International (e.g. ICRP, ISO)
A – Advisory (from TECHREC)

Recommendations, #1

Chapter C, Monitoring Programmes:

Q4: How should the need for an individual monitoring programme be determined and what type of monitoring programme should be selected?		
C08	A	The basis of the evaluation should be available **data from earlier monitoring programmes** (individual or workplace monitoring) and/or results of dedicated **measurements currently performed at the workplace to characterise radiological conditions**. If no such data are available, the **decision factor approach** [IAEA 1999a] should be employed.

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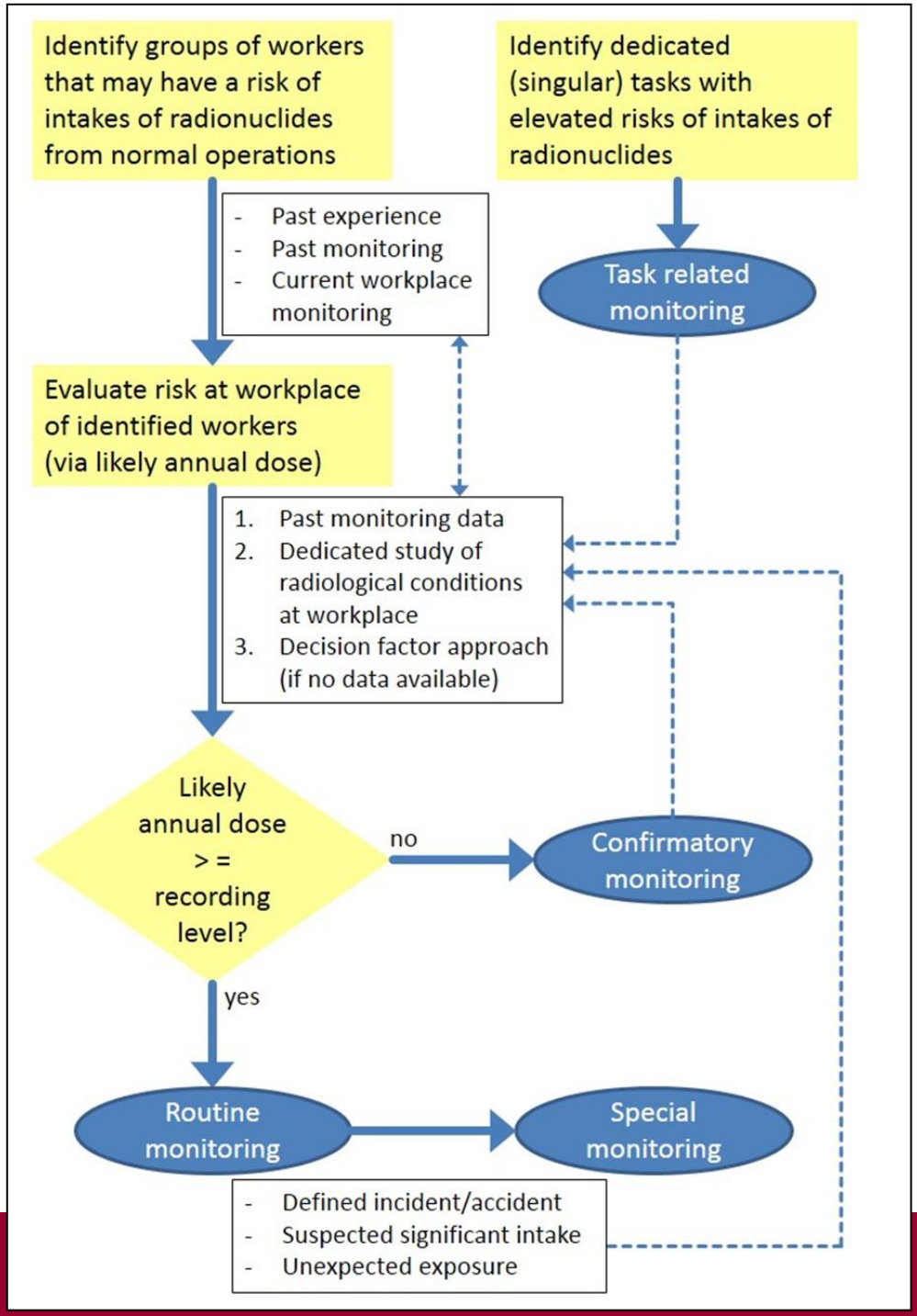
Figure C.1 Identification of workers, determination of the need for monitoring, and selection of a suitable monitoring programme

Solid lines indicate decisions taken, while dashed lines indicate information flow



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Recommendations, #2

Chapter D, Methods of Individual and Workplace Monitoring:

Q2: How should *in vivo* bioassay of the activity of radionuclides retained in the body that emit penetrating radiation be performed?		
D02	I	***In vivo* measurement** of radionuclides in the body should be employed **for radionuclides emitting penetrating radiation** that can be detected outside of the body (mainly high energy X-ray and gamma emitting radionuclides) wherever feasible [ICRU 2003; IAEA 1996]. Methods should satisfy the **performance criteria** for radiobioassay set by **ISO 28218:2010** [ISO 2010b].
D03	I	For radionuclides that are X/gamma emitters (>100 keV) and are rapidly absorbed from the respiratory tract into the body (e.g. ^{137}Cs, ^{60}Co), **whole body monitoring** using **NaI(Tl)** scintillation detectors and/or **HPGe** semiconductor detectors should be performed [ICRU 2003; IAEA 1996]
D04	I	**Monitoring of specific organs** using NaI(Tl) scintillation detectors and/or HPGe semiconductor detectors should be performed for X/gamma emitting radionuclides that concentrate in particular organs or tissues (e.g. ^{131}I in the thyroid) [ICRU 2003; IAEA 1996]

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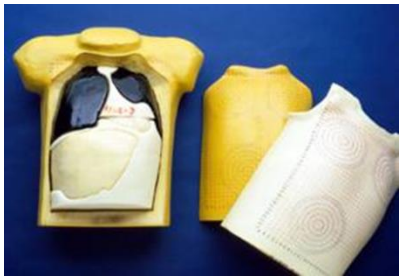
Recommendations, #3



Chapter D, Methods of Individual and Workplace Monitoring:

Q2: How should *in vivo* bioassay of the activity of radionuclides retained in the body that emit penetrating radiation be performed?		
D08	I	To **calibrate** *in vivo* monitoring systems for measurements of radionuclides distributed in all or part of the body, laboratories should use **active physical phantoms** simulating internal contamination of organs or total body [ICRU 2003; IAEA 1996].
D10	I	Calibrations should be performed using phantoms that simulate the organ of interest. The size of the calibration phantom and the distribution of the radionuclides should match that expected in the human subject [ICRU 2003; IAEA 1996].
D12	A	**Numerical calibration techniques may be used** as an alternative tool for *in vivo* measurement calibrations. It is recommended that national competent authorities consider adapting approval protocols of *in vivo* monitoring laboratories to allow the use of numerical calibration techniques, subject to the implementation of an appropriate quality assurance programme that includes **appropriate validation procedures**.

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Recommendations, #4

Chapter E, Routine and Special Dose Assessment:

Q8: How should dose assessments after routine monitoring be performed in practice?		
E08	I	The recommended approach comprises the **ISO 27048:2011 approach** (left side of Figure E.1 and Table E.1) [ISO 2011], and, when the analysis indicates that the annual dose limit may potentially be exceeded, the **IDEAS Guidelines** [EURADOS 2013].

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ISO 27048:2011

- provides a structured approach for performing internal dose assessments
- aims to ensure that the level of effort applied in the evaluation corresponds to the magnitude of the exposure

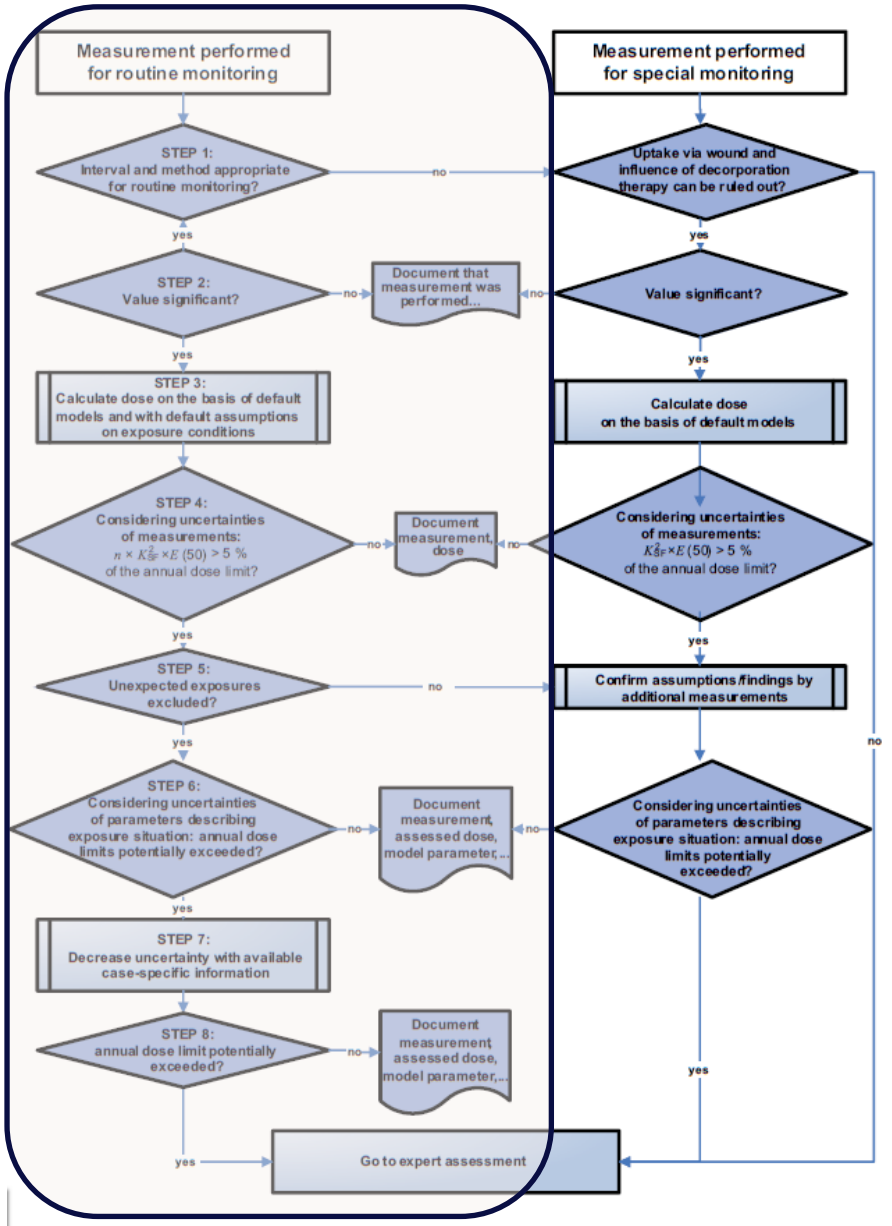

Figure 2 — Procedure for assessment of doses on basis of individual measurements

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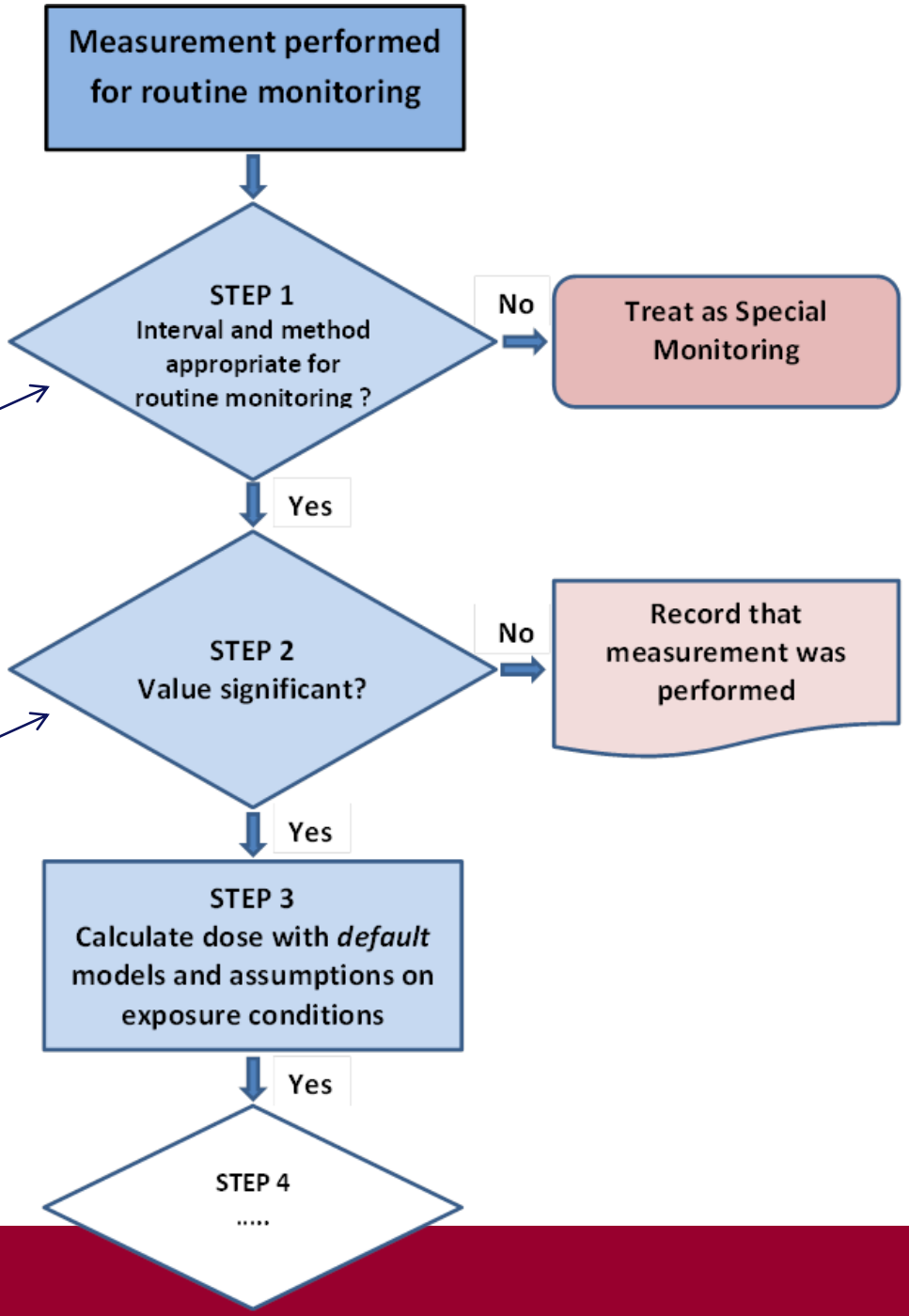
ISO 27048:2011

Meets ISO 20553:2006 requirements ?

Does the measured bioassay value exceed:

- Decision Threshold, and
- Critical value, M_c ?



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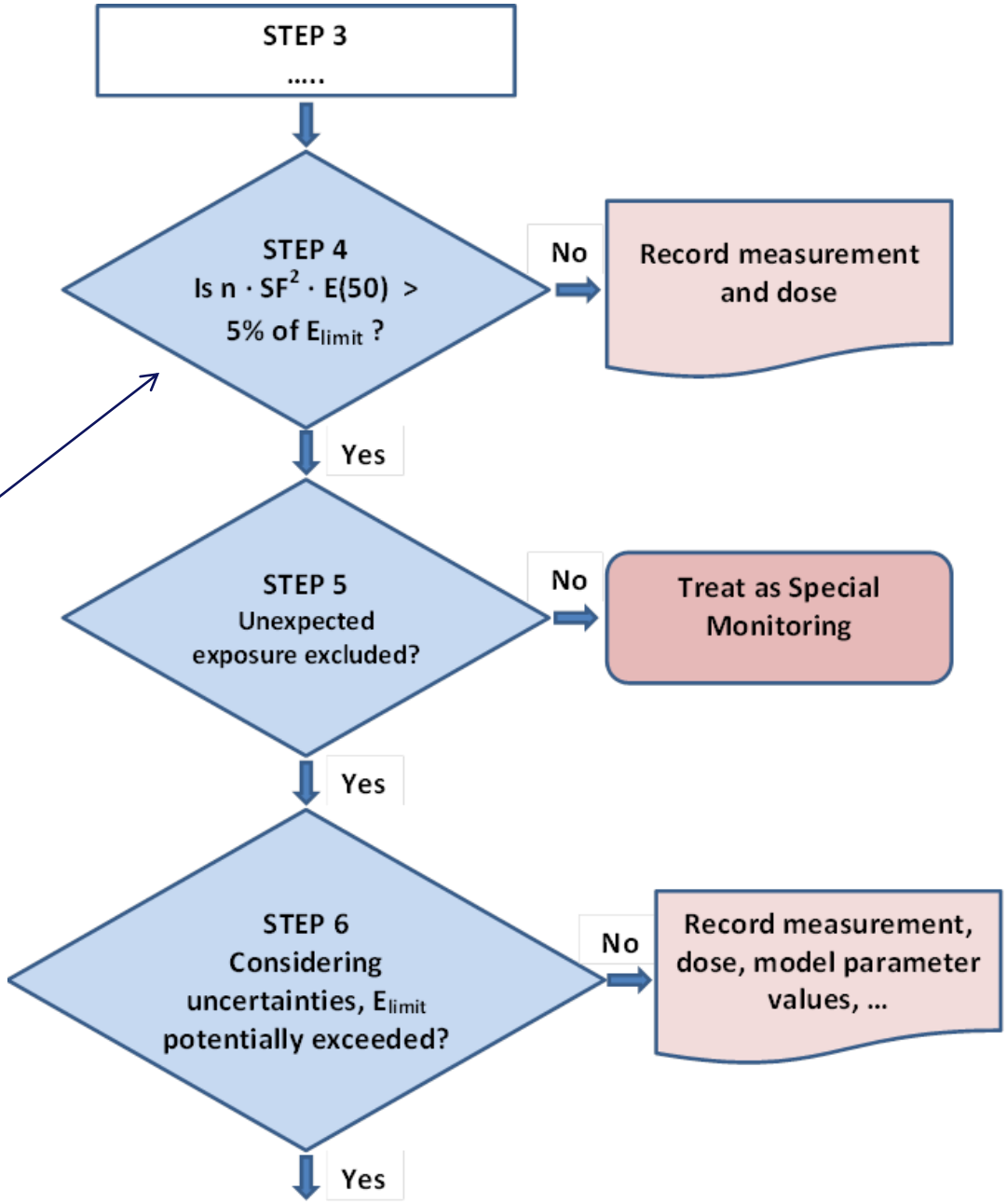
ISO 27048:2011

n number of monitoring periods in year

SF total Scattering Factor for the bioassay measurement

E(50) committed effective dose assessed from the measurement

E_{limit} annual dose limit, 20 mSv



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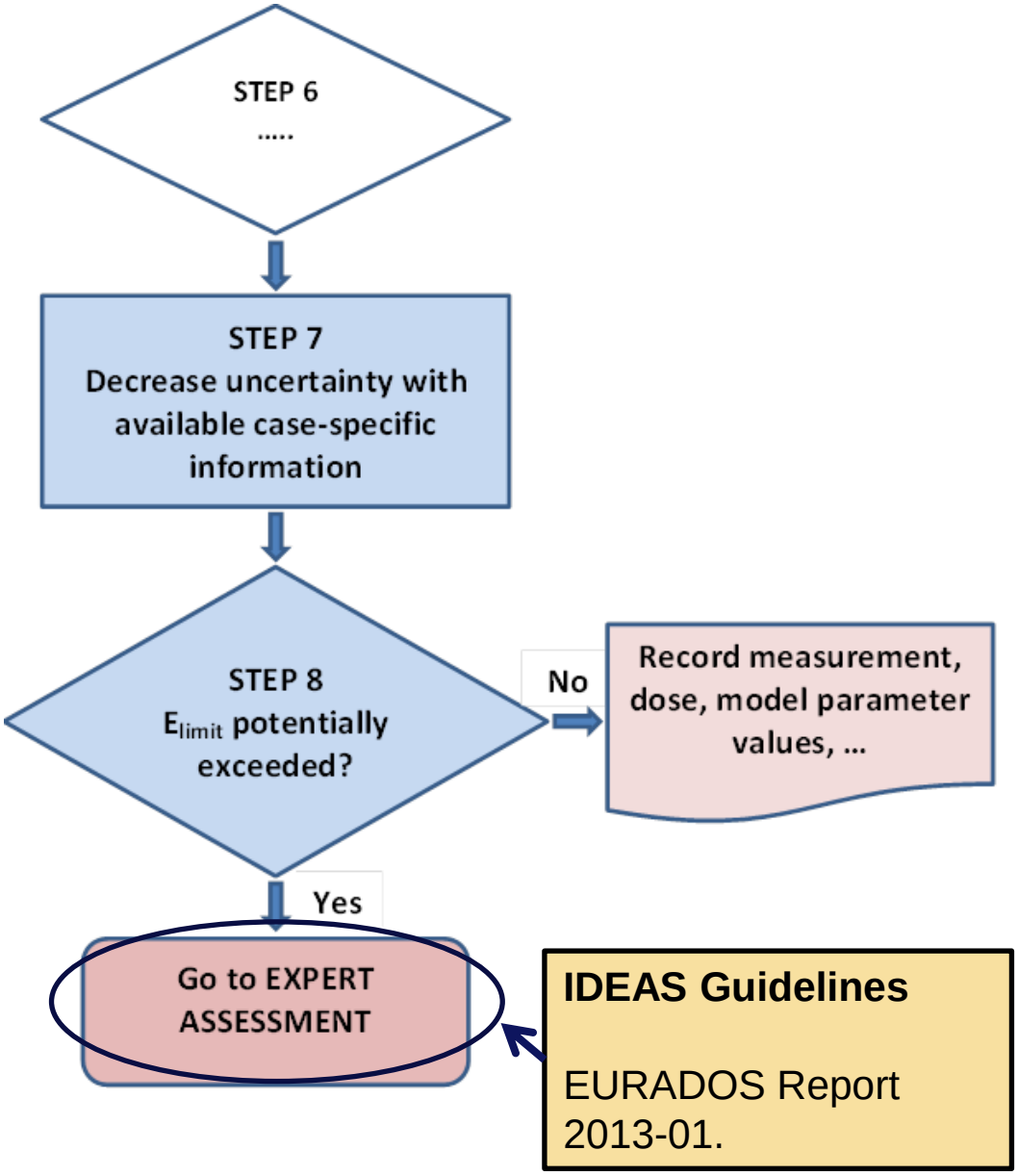
ISO 27048:2011



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Recommendations, #5

Chapter E, Routine and Special Dose Assessment:

Q7: What are the issues that might prevent a straight-forward interpretation of individual monitoring data?		
E06	A	Dose assessors should be aware of a number of **confounding factors** that can result in erroneous dose assessments: external contamination of the body, treatment with medical radioisotopes, contamination of bioassay samples, errors in the bioassay sample collection period, background radiation in *in vivo* monitoring, contribution to *in vivo* measured counts from activity in other organs, dietary intakes (for NORM materials), independent biokinetic behaviour of radioactive progeny used to monitor for intake of the parent, independent biokinetic behaviour of mixtures of radionuclides, radionuclides in an unusual physical or chemical form.

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Effect of confounding factors -1

External contamination

External contamination may be mis-interpreted as internal contamination if decontamination of skin and clothing is not fully effective.

Treatment with medical radio-isotopes

Individuals being monitored may have received an intake of a radionuclide as a result of medical treatment, but may be unaware of it.

Contamination of bioassay samples

Samples may be contaminated if sampling protocols have not been established and validated. A particular problem is intakes of insoluble materials because urine sample activities are then likely to be very low.

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Effect of confounding factors - 2

Dietary intakes

Measurements in bioassay samples of uranium and thorium isotopes and their daughter radionuclides may include contributions from dietary intakes received away from the workplace. ISO 16638-1:2015 advises on how to establish an appropriate correction or reference value for the contribution from dietary intake.

Independent biokinetic behaviour of daughter radionuclides used to monitor for intake of the parent

e.g. *in vivo* measurement of ^{214}Pb and ^{214}Bi for monitoring a ^{238}U intake

Radionuclides in Unusual Chemical Forms

e.g. ^{3}H-DNA bases, ^{18}F-glucose

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Recommendations, #6

Chapter E, Routine and Special Dose Assessment:

Q16: Which doses should be estimated in case of contaminated wounds?		
E16	M	In the case of wounds, both the **equivalent dose to the area of wounded skin** and the **committed effective dose resulting from uptake** from the wound site should be quantified.
E18	I	A special monitoring programme should be implemented for wound cases by a combination of ***in vivo* and *in vitro* measurements** in order to estimate the systemic uptake. In order to evaluate the committed effective dose: • to a first order of magnitude, the assessment should be made assuming a **direct injection into blood** [SFMT 2011; EURADOS 2013]; • depending on circumstances, a more precise wound model may be used. The excretion and retention functions of the **NCRP Publication 156 wound model** and dose coefficients for radionuclides using a wound model combined with systemic models [Ishigure 2003; Toohey 2011] could be used.

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Recommendations, #7

Chapter F, Accuracy Requirements and Uncertainty Analysis:

Q1: Under what circumstances should uncertainties in assessed dose be assessed, and how should information on uncertainties be used?		
F01	I	The uncertainty on assessed dose should be considered: • in the **design** of a monitoring programme [ICRP 2015b; ISO 2006]; • to assess the **reliability** of a monitoring procedure [ISO 2011]; and • for the assessment of **risks to health** [ICRP 2007].

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Recommendations, #8

Chapter G, Quality Assurance and Criteria for Approval and Accreditation:

Q2: How should the reliability of monitoring data used in the assessment of internal doses be guaranteed?		
G02	I	It is recommended that monitoring should conform to the **performance criteria** of the ISO standards on internal dosimetry [ISO 2006; 2010; 2011; 2015d, 2016b] and ISO/IEC 17025:2005 [ISO/IEC 2005]. Participation in **inter-laboratory measurement intercomparison programmes** is recommended.
Q3: How should the reliability of assessments of dose due to occupational intakes of radionuclides be guaranteed?		
G03	I	It is recommended that dose assessment procedures should conform to the **quality assurance and quality control criteria** and recommendations established in ICRP publications [ICRP 2007; 2015b], ISO 27048:2011 [ISO 2011], the IDEAS Guidelines [EURADOS 2013], IAEA publications [e.g. IAEA 2014] and the 2013 Directive [EC 2014]. Participation in **intercomparison programmes of dose assessments** of internal exposures is recommended.

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The team

- included experts from:

France, Germany, Italy, Spain, UK

Luxembourg, 2014

The TECHREC TEAM

Role	Name	Organisation
Project Leader & Task Leader	Dr George Etherington	**PHE**
Task Leaders	Dr Philippe Bérard	**CEA**
	Dr Eric Blanchardon	**IRSN**
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	Dr Carlo-Maria Castellani	**ENEA**
	Dr Didier Franck	**IRSN**
	Dr Augusto Giussani	**BfS**
	Dr Maria Antonia Lopez	**CIEMAT**
	Dr James Marsh	**PHE**
	Dr Dietmar Nosske	**BfS**
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https://ec.europa.eu/energy/en/radiation-protection-publications

Acknowledgement
The TECHREC project was funded by the European Commission (Directorate-General for Energy, DG ENER) under Service Contract Number ENER/2014/NUCL/SI2.680087

Questions?

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Supplementary slides

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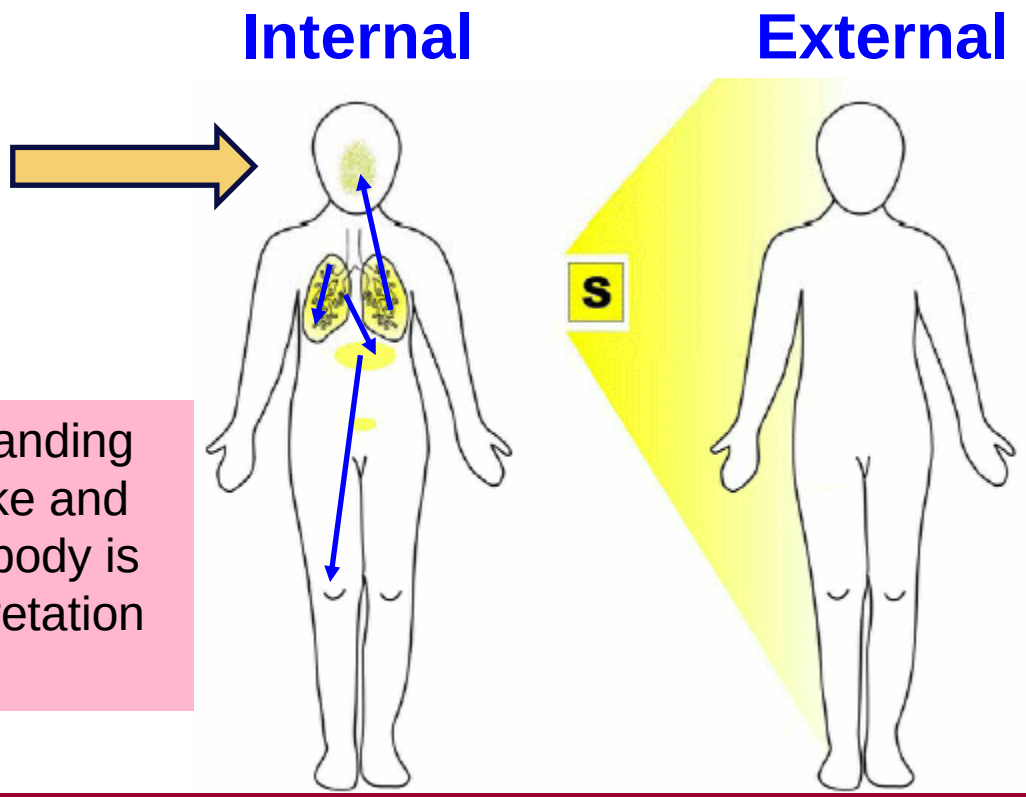
Differences between internal and external dosimetry - I

The source of irradiation is the decay of radionuclides in the organs of the body

Radionuclide intake:
Inhalation, ingestion, …



TECHREC: An understanding of the modelling of intake and initial deposition in the body is important for the interpretation of monitoring data

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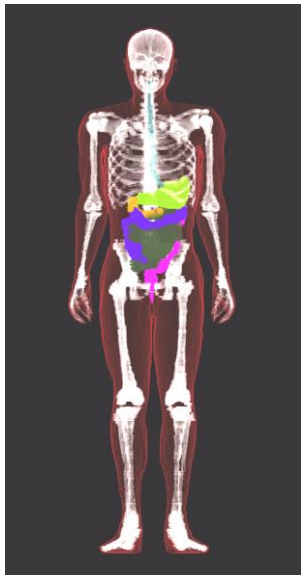
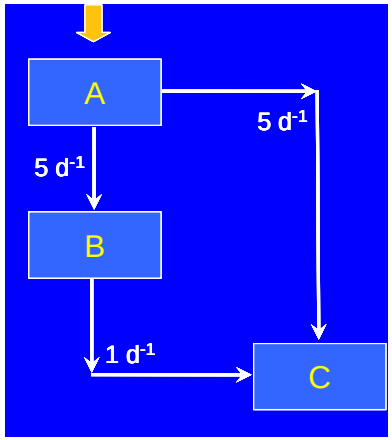
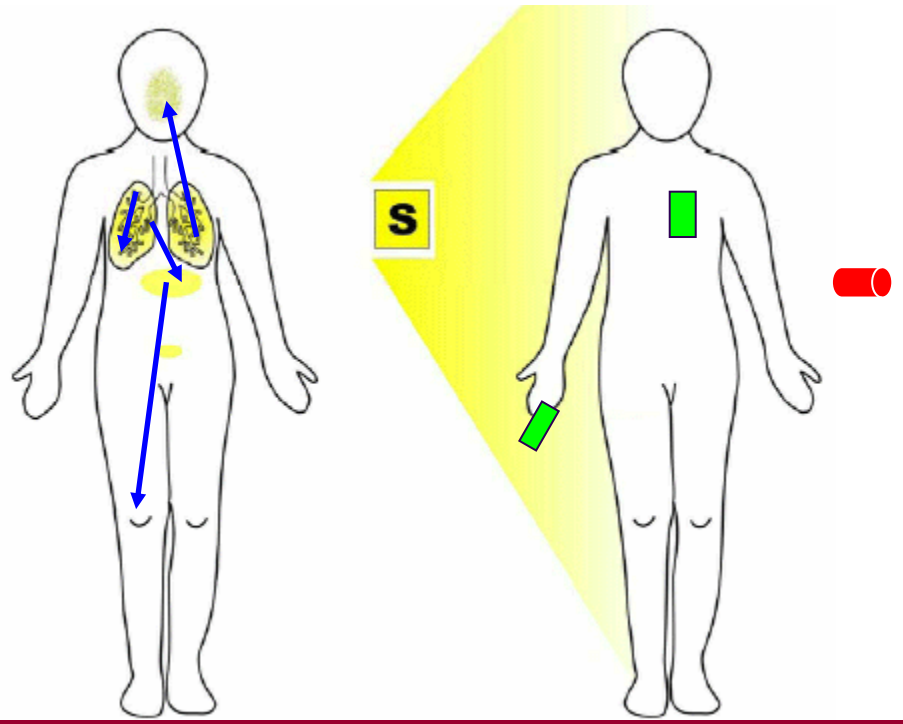
Differences between internal and external dosimetry - II

Internal doses can't be measured directly (and so models have to be used extensively)







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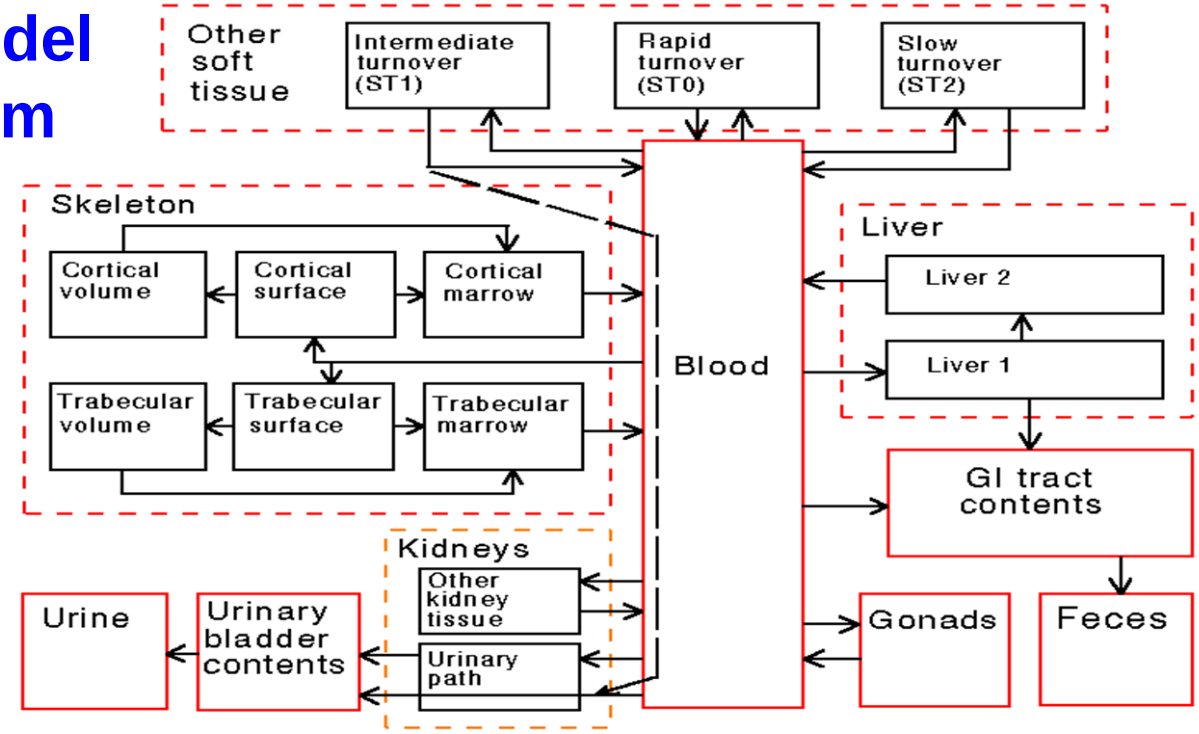
Differences between internal and external dosimetry - II

Internal doses can't be measured directly (and so models have to be used extensively)

Systemic model for plutonium

TECHREC: Guidance is needed on the practical aspects of the use of these models for individual dose assessment, particularly for interpretation of bioassay data



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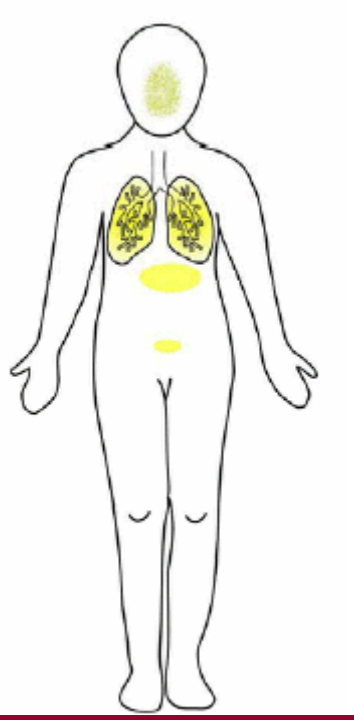
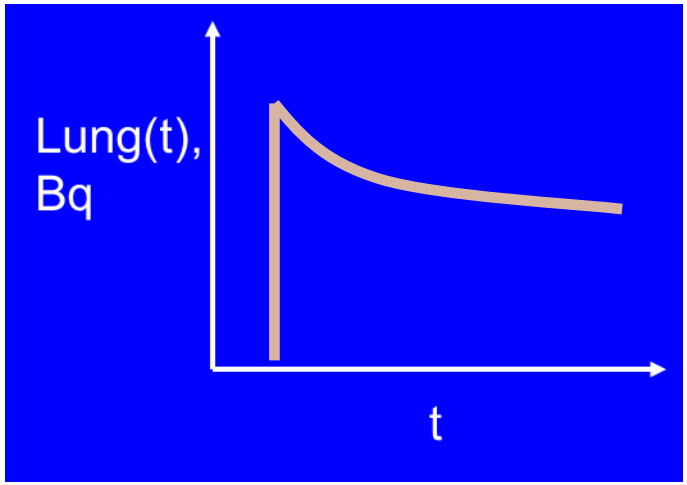
Differences between internal and external dosimetry - III

Internal doses are protracted over time

Internal

TECHREC: An understanding of the time dependence of doses to organs is important, particularly with respect to health risk assessment





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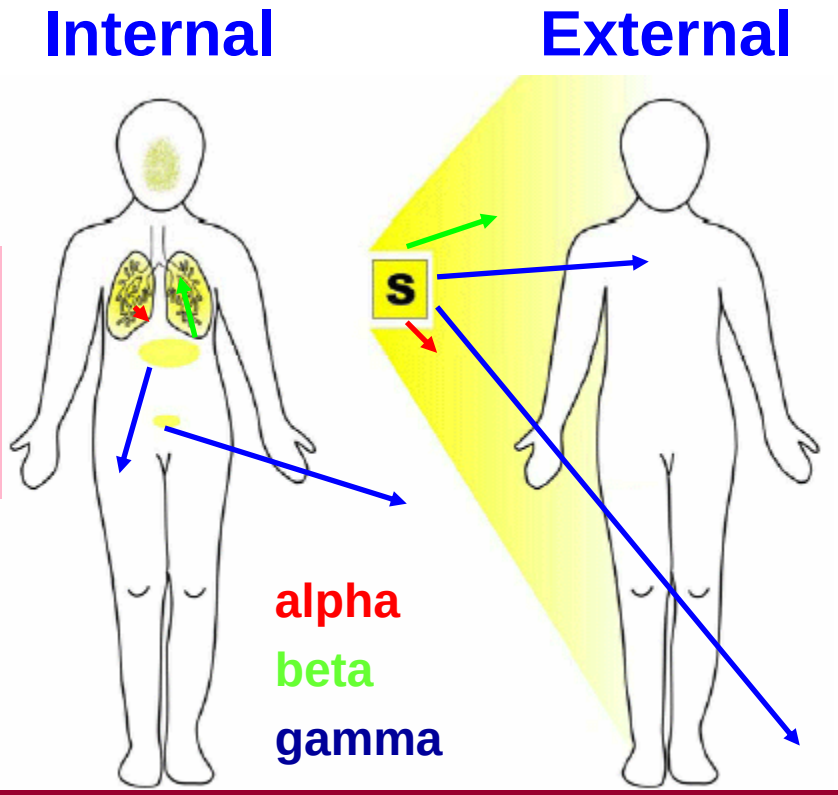
Differences between internal and external dosimetry - IV

Short range (non-penetrating) radiation (α, β, etc.) make a significant contribution to internal dose

TECHREC: Guidance is needed on individual dose assessment for the different classes of radionuclides



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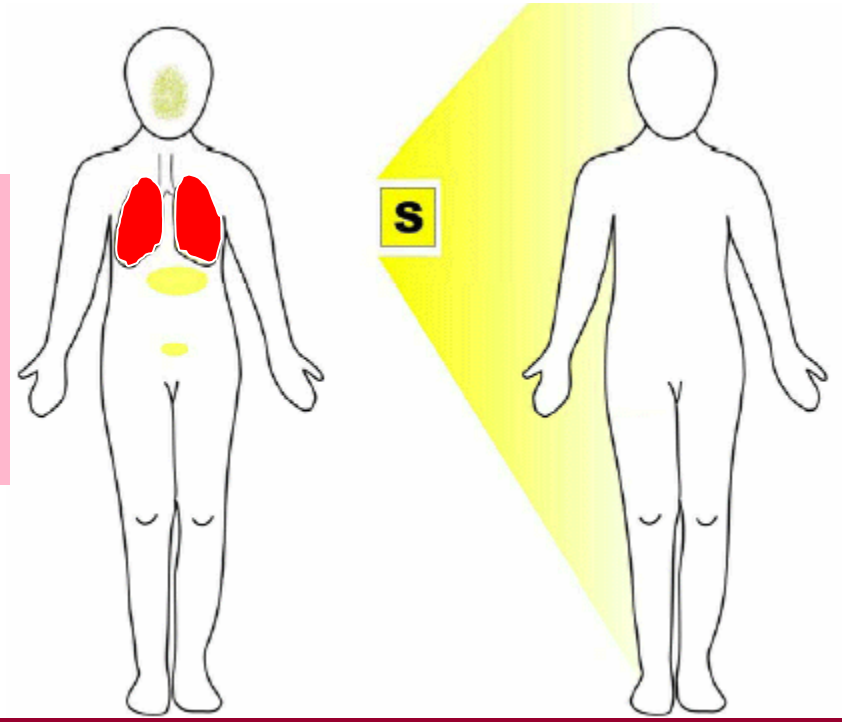
Differences between internal and external dosimetry - V

The distribution of absorbed dose between organs is often very inhomogeneous

Internal **External**



TECHREC: An understanding of the dose distribution in the body is needed, particular with respect to health risk assessment

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Participants in the Stakeholder Consultation

Stakeholders at national level

- 22 European Union countries
- 10 non-EU countries
- 227 people invited to comment

EURADOS Working Group 7 members

A Group of "Highly-Qualified Experts in Internal Dosimetry"

An "International" Group (ICRP, IAEA, …)

A Group of Experts on Radon Dosimetry

The EURATOM Article 31 Group of Experts (separately)

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Recommendations, #1

Chapter C, Monitoring Programmes:

Q3: How should workers be identified for whom individual monitoring may be required?		
C04	M	Systematic monitoring is mandatory for workers liable to receive effective doses greater than 6 mSv per year (category A). For other workers (category B), monitoring should be sufficient to demonstrate that the classification is correct. [EC 2014]
C05	I	In general, the assignment of a monitoring programme to an individual should be based on the likelihood that the individual could receive an intake of radioactive material exceeding a predetermined level, as a result of normal operations or in the event of an accident [ICRP 2015b].
C06	A	The evaluation of the likelihood of intakes for groups of workers should be based on past experience and past and current monitoring data if available.