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Red de Optimización de Protección Radiológica Ocupacional en LatinoAmerica y Caribe

Interpretation of measurements and dose assessment of internal occupational exposures

Nancy Puerta Yepes

Autoridad Regulatoria Nuclear

IAEA ORP WEBINAR: Tips and Tricks for the Practice of Internal Dosimetry in Occupational Radiation Protection

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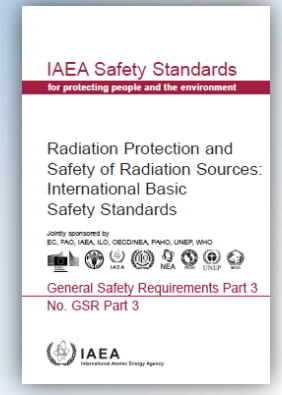

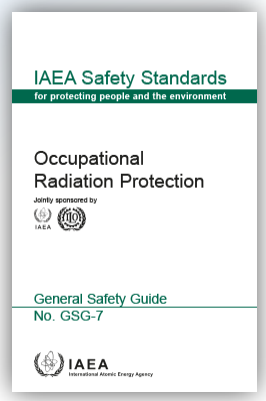

Interpretation of measurements and dose assessment of internal occupational exposures

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1. Models in internal dosimetry
2. Assessment of dose from measurements (interpretation)
3. Software
4. Reference values
5. Monitoring interval
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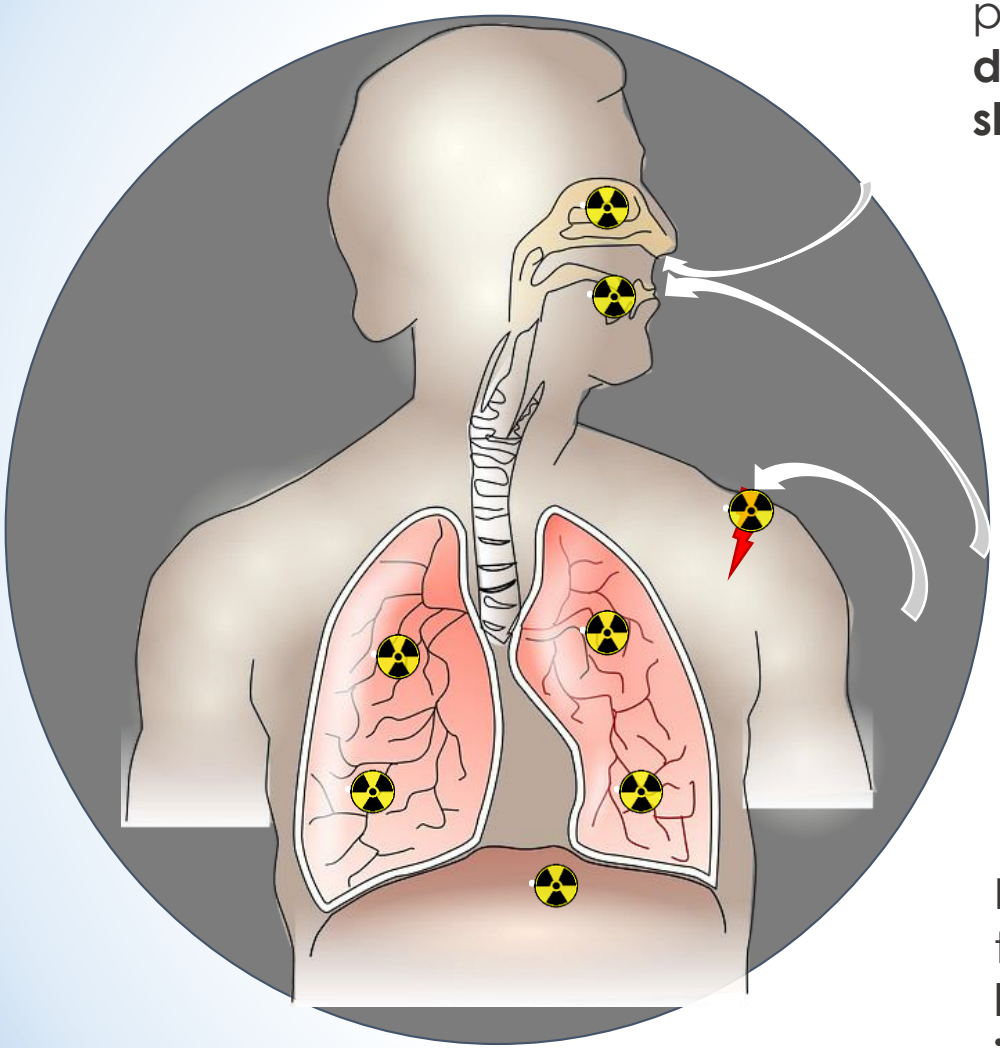
Biokinetic Models



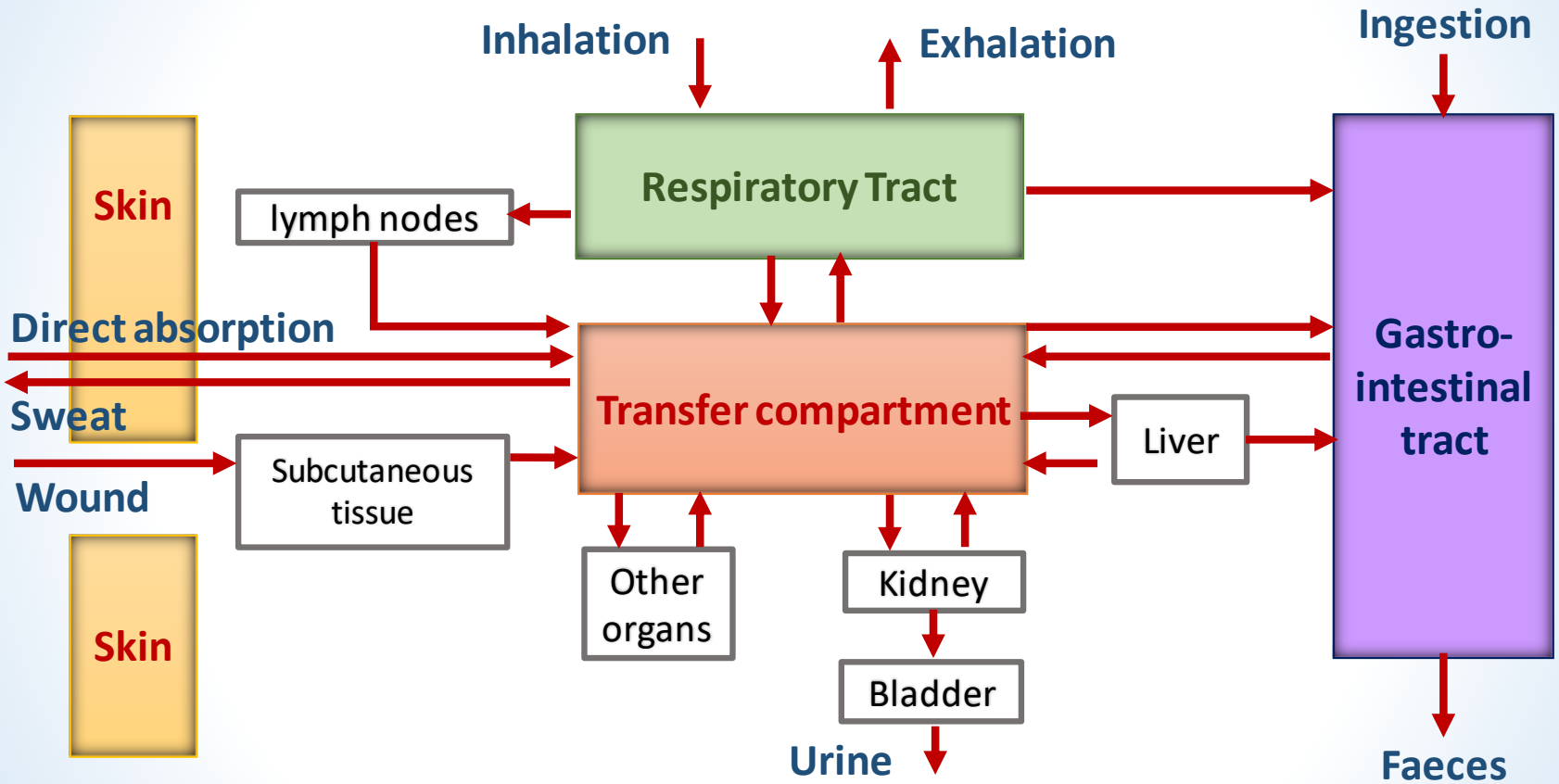
- Occupational **intakes** of radionuclides can occur via various pathways**: inhalation, ingestion and dermal absorption (through intact skin or via a wound**)

Once the radionuclides enter into the human body, they can deposit in lungs, alimentary tract, transfer into blood and translocate to other organs and tissues. A fraction of this radioactive material is excreted outside of the body through the kidneys and the intestines.

For dose assessment, we first need to know these **dynamic behaviours of radionuclides inside human body, which are described by biokinetic models.**

Biokinetic Models

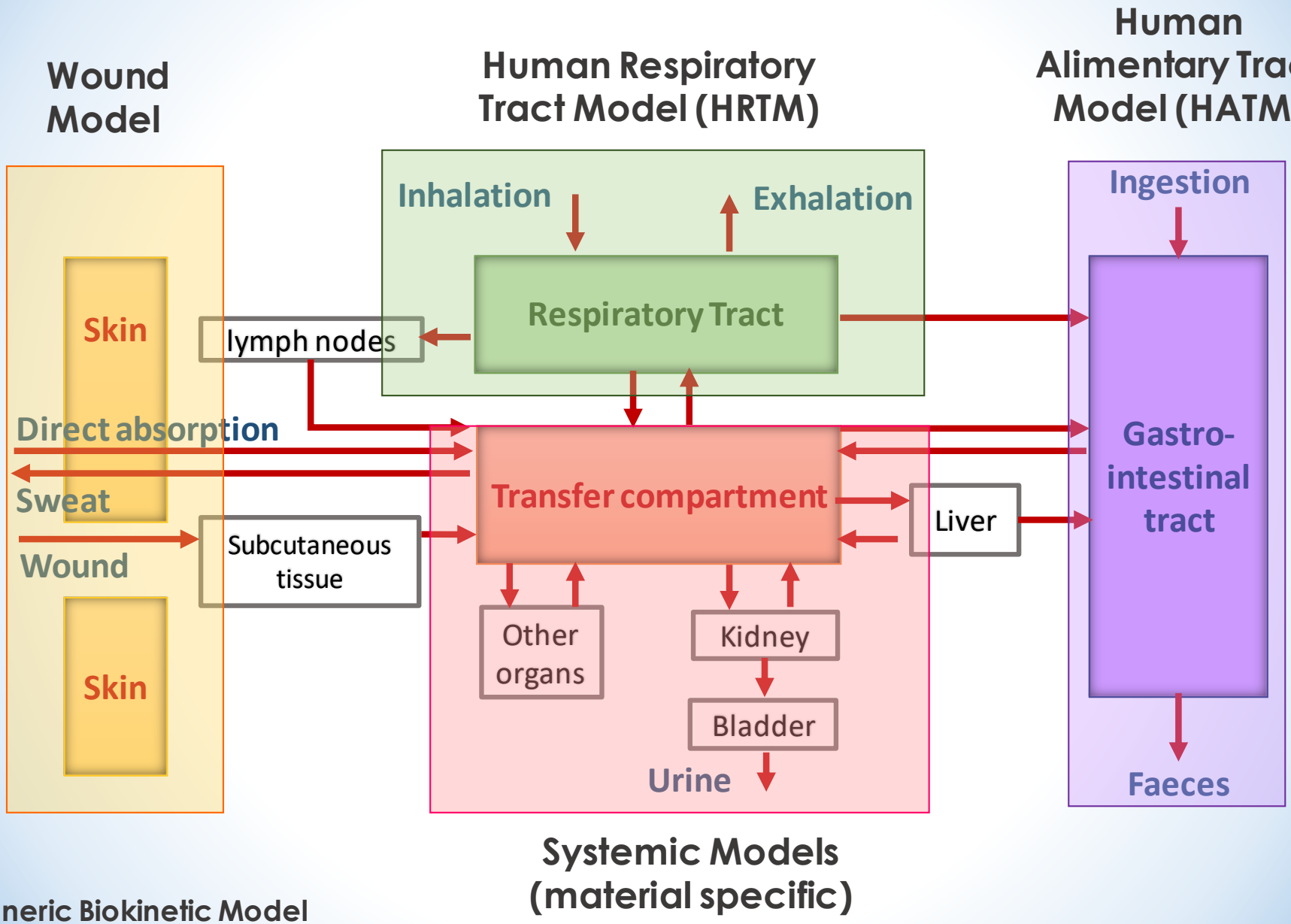
- Specific models for workers have been developed by the **INTERNATIONAL COMMISSION ON RADIOLOGICAL PROTECTION (ICRP).**



Generic Biokinetic Model (ICRP 78, 1997)

- The general approach of ICRP is to use **compartmental structures**, where specific organs and tissues are represented by interconnected compartments.

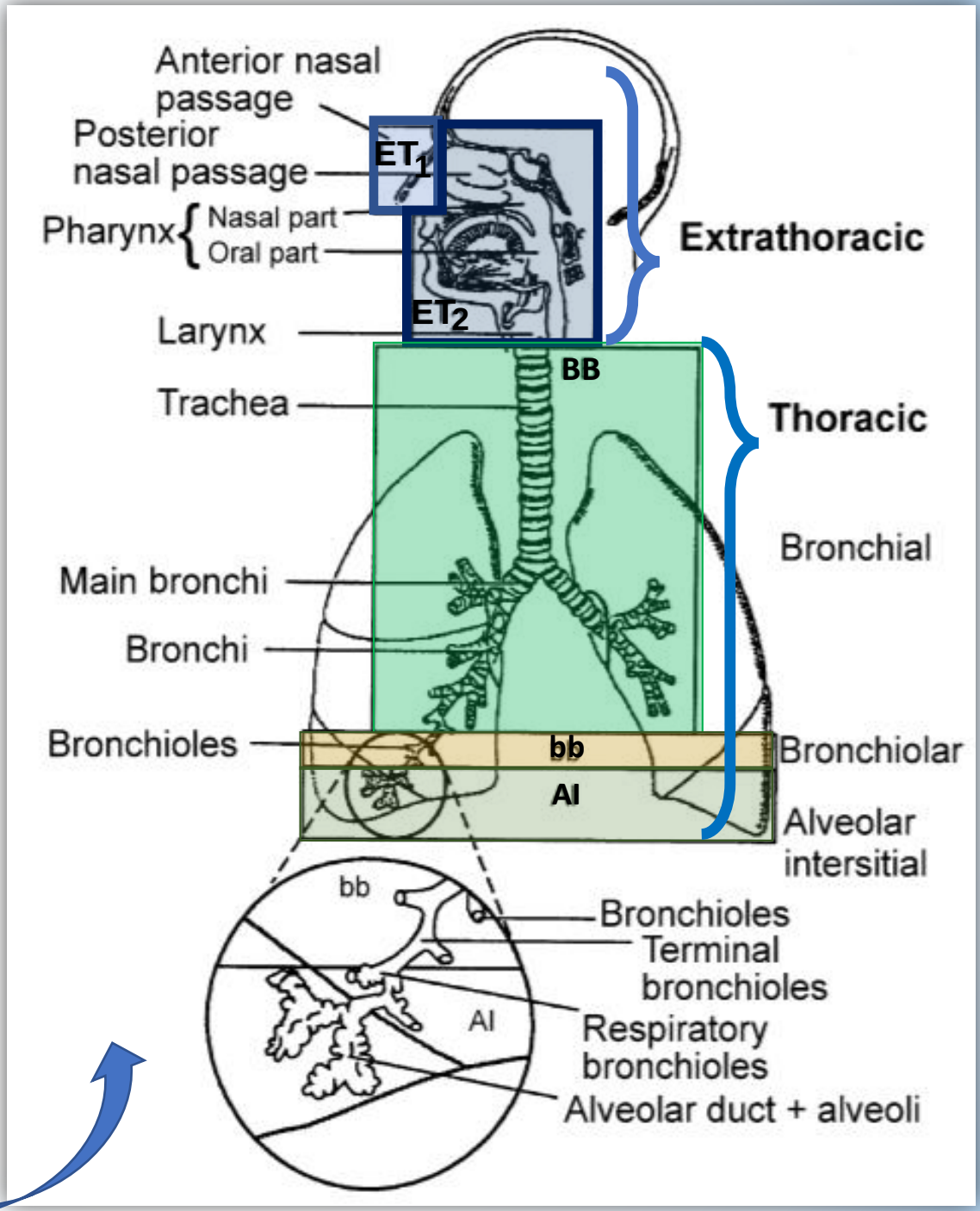
Biokinetic Models



Generic Biokinetic Model (ICRP 78, 1997)

Human Respiratory Tract Model (HRTM)

- For occupational exposure, **the main route of intake is by inhalation**
- The human respiratory tract model is described in **ICRP 66 (1994)** and, a revised version in **ICRP 130 (2015)**
- Guidance on the use of the human respiratory tract model can be found in ICRP Supporting Guidance 3(2002)



Respiratory tract regions defined in the HRTM (ICRP 66,1994)

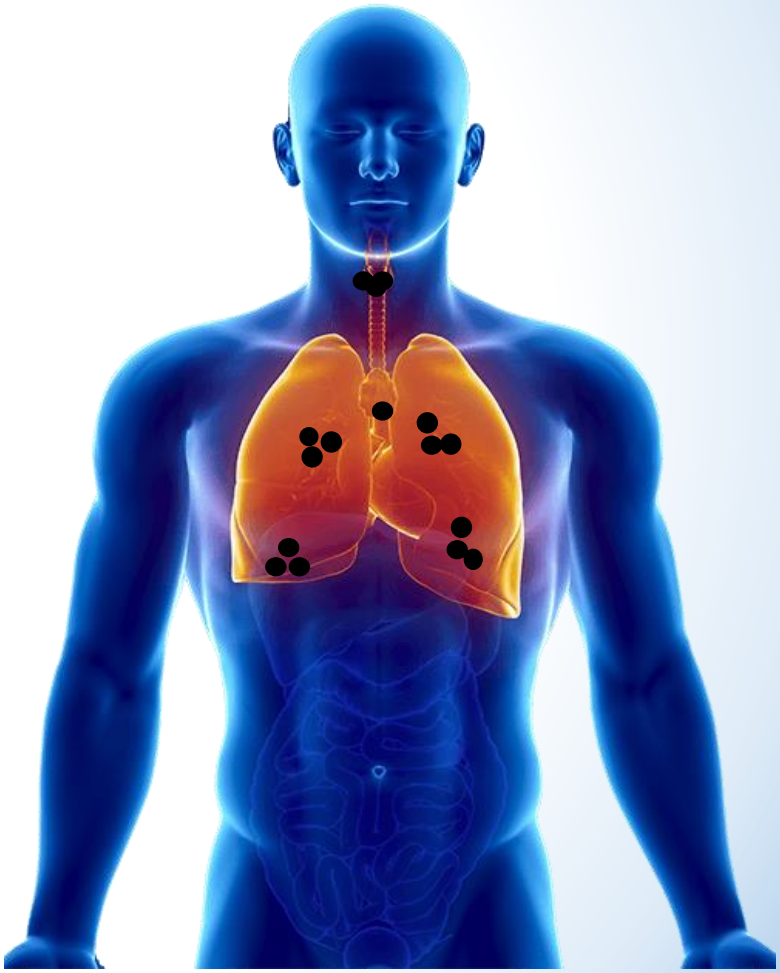
Human Respiratory Tract Model (HRTM)

The human respiratory tract model treats **deposition and clearance of inhaled radionuclides separately**

Deposition of inhaled particulates is calculated for each region **as a function of particle size and breathing parameters →AMAD** (parameter related to particle size)

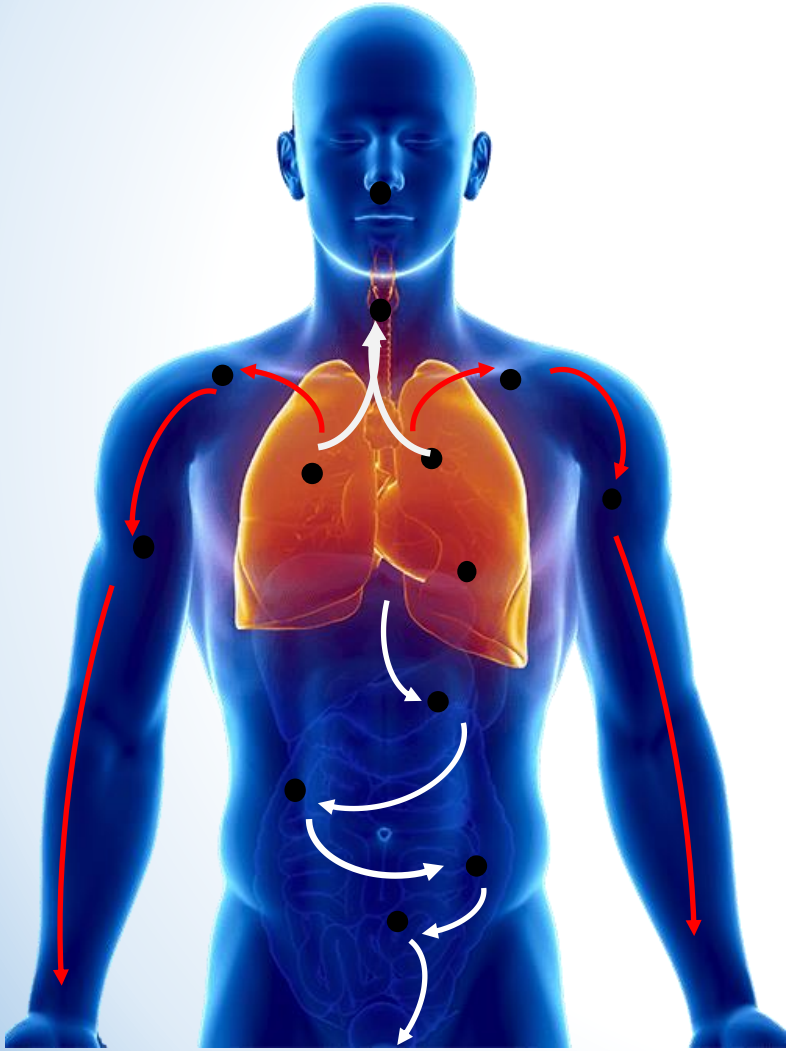
- An **AMAD of 5 µm** is considered to be the most appropriate default particle size for radionuclides in the workplace.
- For inhalation of radionuclides by workers, the reference subjects are taken to be normal nose breathing persons undertaking **light work**.

Deposition



Human Respiratory Tract Model (HRTM)

Clearance



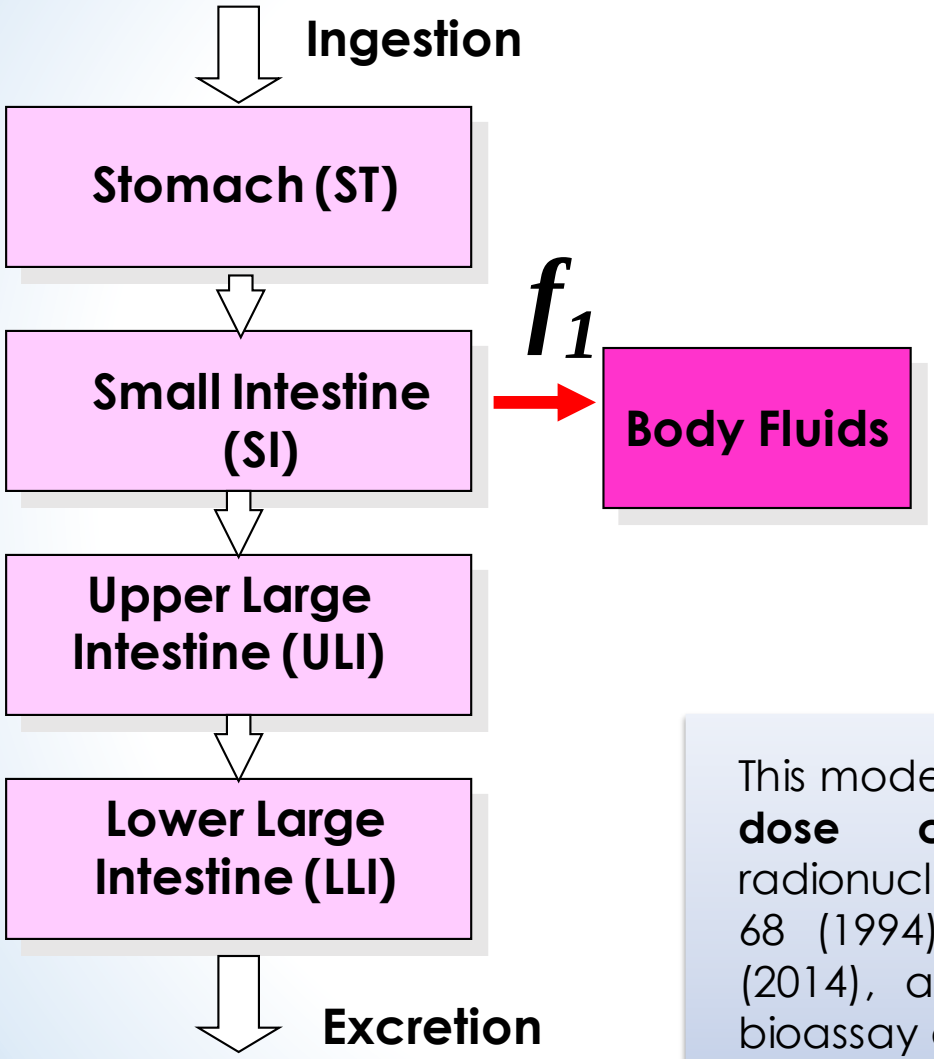
Clearance from the respiratory tract is treated as two competing processes:

- **Absorption to blood**
- **Particle transport** (by mucociliary clearance or translocation to lymph nodes)

Most of the deposited material that is not absorbed to blood is cleared to the gastrointestinal tract by particle transport

The absorption to the blood in the respiratory tract is given by **three default solubilities: Type F (Fast), M (Moderate) and S (Slow)**

Gastrointestinal tract, ICRP 30 (1979)



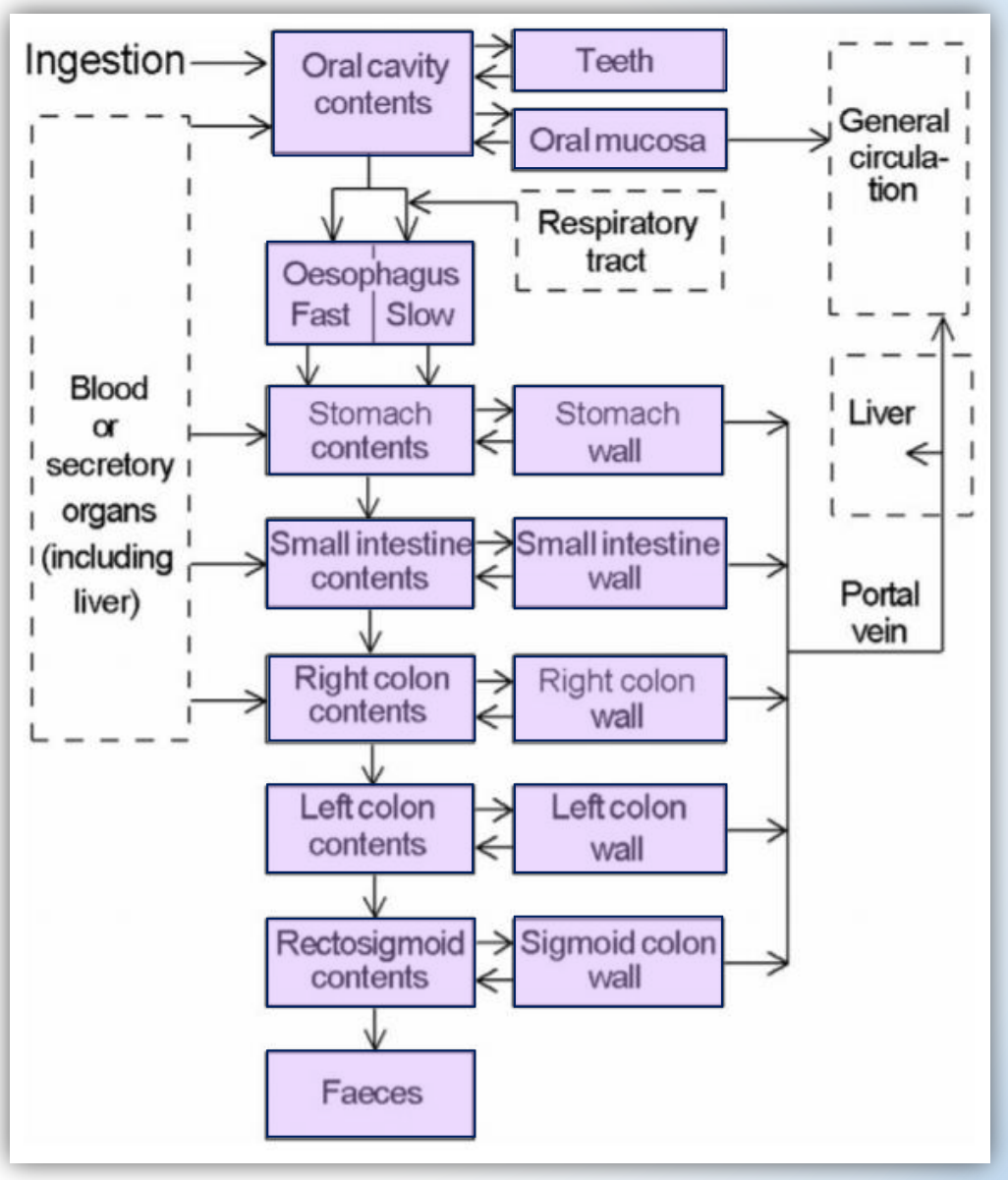
For describing the behaviour of ingested radionuclides there are **two models:**

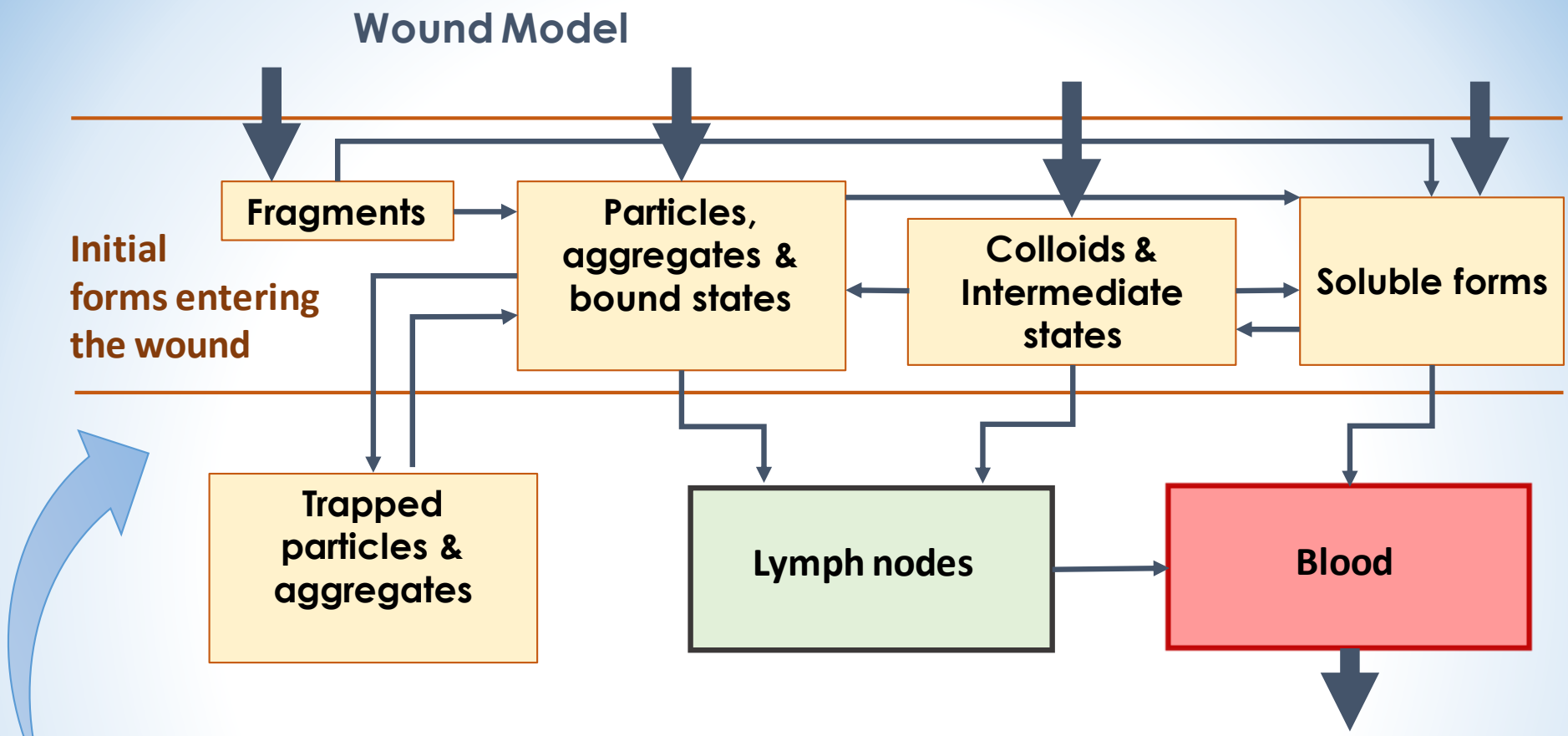
- The first model is described in **ICRP 30 (1979)** and
- The **new model: the human alimentary tract model**, is described in **ICRP 100 (2006)**

This model forms the calculation basis for the **dose coefficients** for ingestion of radionuclides by workers presented in ICRP 68 (1994) and **table III.2A of GSR Part 3** (2014), and also for the interpretation of bioassay data in ICRP 78 (1997)

Human Alimentary Tract Model (HATM), ICRP Publication 100 (2006)

New dose coefficients and recommendations for the interpretation of bioassay data, on the basis of this new human alimentary tract model, have recently been published by the **ICRP (OIR series)**





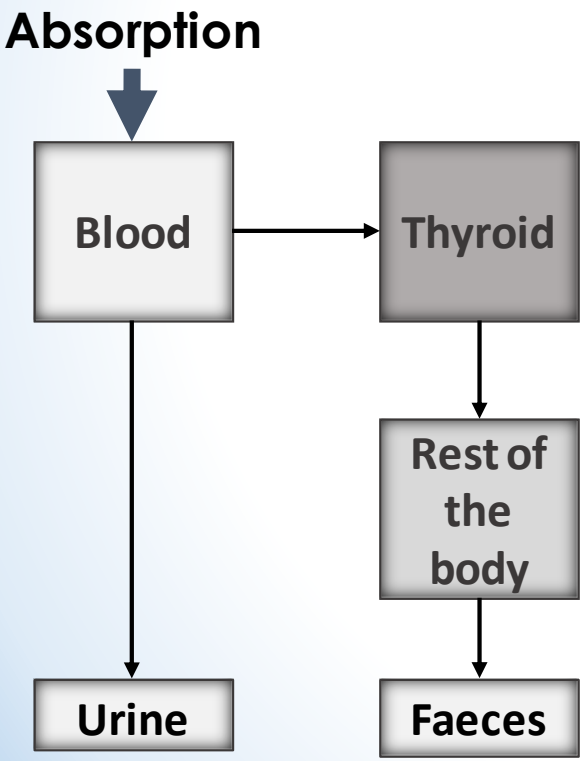
Schematic representation of the National Council on Radiation Protection and Measurements (NCRP) **wound model, NCRP (2007).**

Dose coefficients for incorporation of radionuclides through wounds have been calculated for 38 radionuclides [Health Phys. **100** (2011) 508–514] using a wound model NCRP (2007) combined with systemic models used to calculate dose coefficients for workers [ICRP publication 68, 1994].

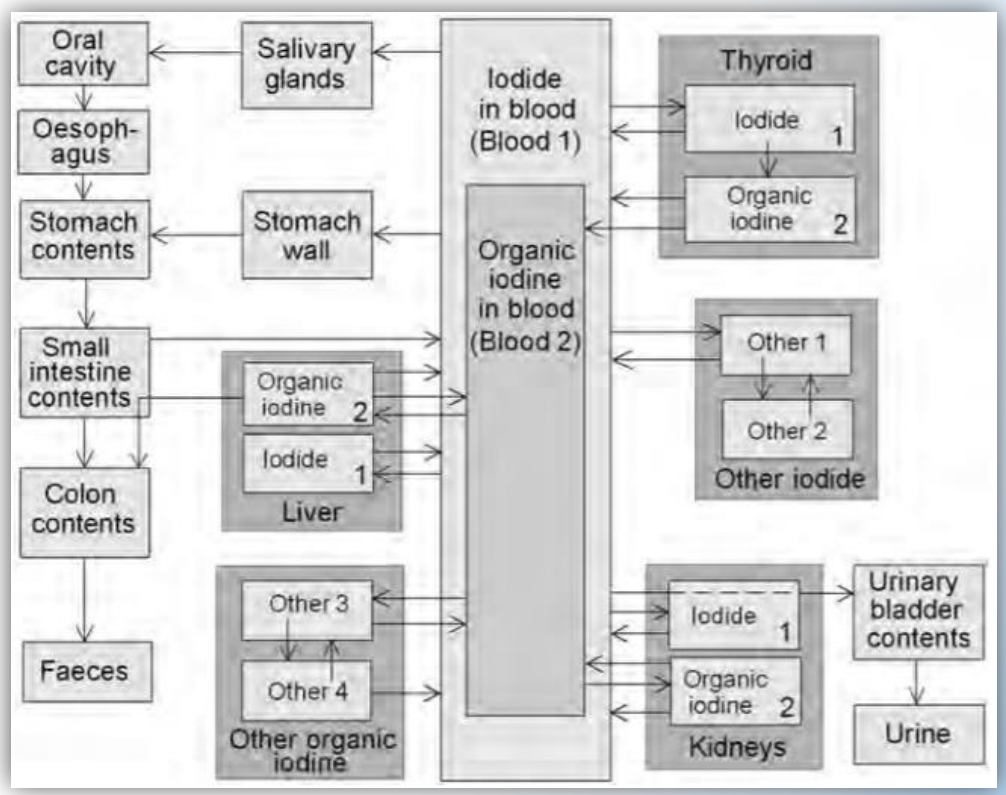
Systemic Models

Each element has a different systemic model

Systemic Model for Iodine, ICRP 78 (1997)



Systemic Model for Iodine, ICRP 137 (OIR part 3, 2017)



Assessment of dose from measurements

- These biokinetic models combined among them, depending on the intake route, form the calculation basis for the dose coefficients for intake of radionuclides by workers.

- **Doses per unit intake (dose coefficients)** for the estimation of the committed effective dose for ingestion and inhalation of radionuclides are given in Tables III.2A–III.2H (**GSR Part 3, ICRP Publication 68**)

TABLE III.2A. WORKERS: COMMITTED EFFECTIVE DOSE PER UNIT INTAKE $e(g)$ VIA INHALATION AND INGESTION (Sv/Bq) (cont.)

Radionuclide[a]	Physical half-life	Inhalation				Ingestion	
		Type	f_1	$e(g)_{1\ \mu m}$	$e(g)_{5\ \mu m}$	f_1	$e(g)$
I-129	1.57×10^{7} a	F	1.000	3.7×10^{-8}	5.1×10^{-8}	1.000	1.1×10^{-7}
I-130	12.4 h	F	1.000	6.9×10^{-10}	9.6×10^{-10}	1.000	2.0×10^{-9}
I-131	8.04 d	F	1.000	7.6×10^{-9}	1.1×10^{-8}	1.000	2.2×10^{-8}

Commited effective dose = Intake × e(g)

- Revision of models and **new dose coefficients for workers are found in the Occupational Intakes of Radionuclides (OIR) series** (ICRP publication 130, 134, 137, 141), but the full set of internal dose coefficients is not completed yet.

Assessment of dose from measurements

How to obtain the Intake I ?

$$I = \frac{M}{m(t)}$$

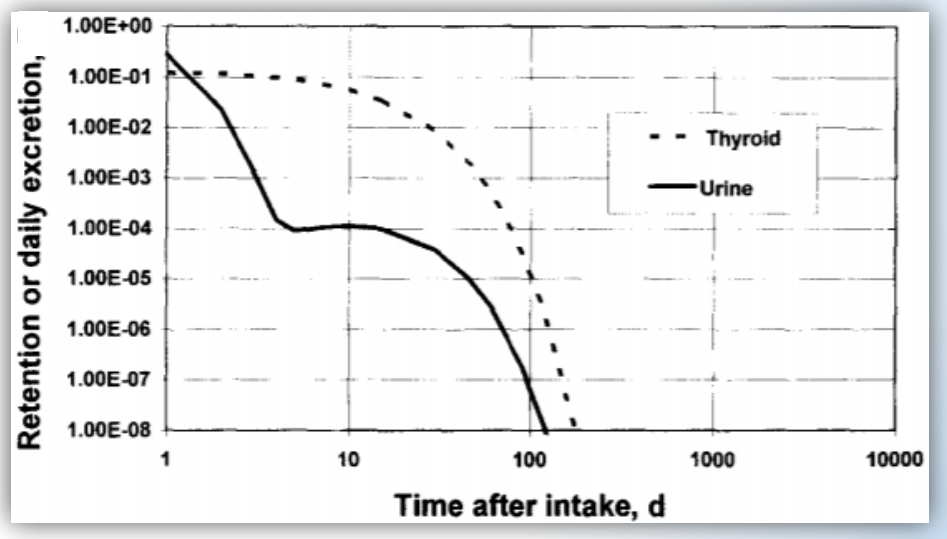
M

Body/ organ content
Excretion rate

$m(t)$

Predicted values of retention or excretion functions using Biokinetic models

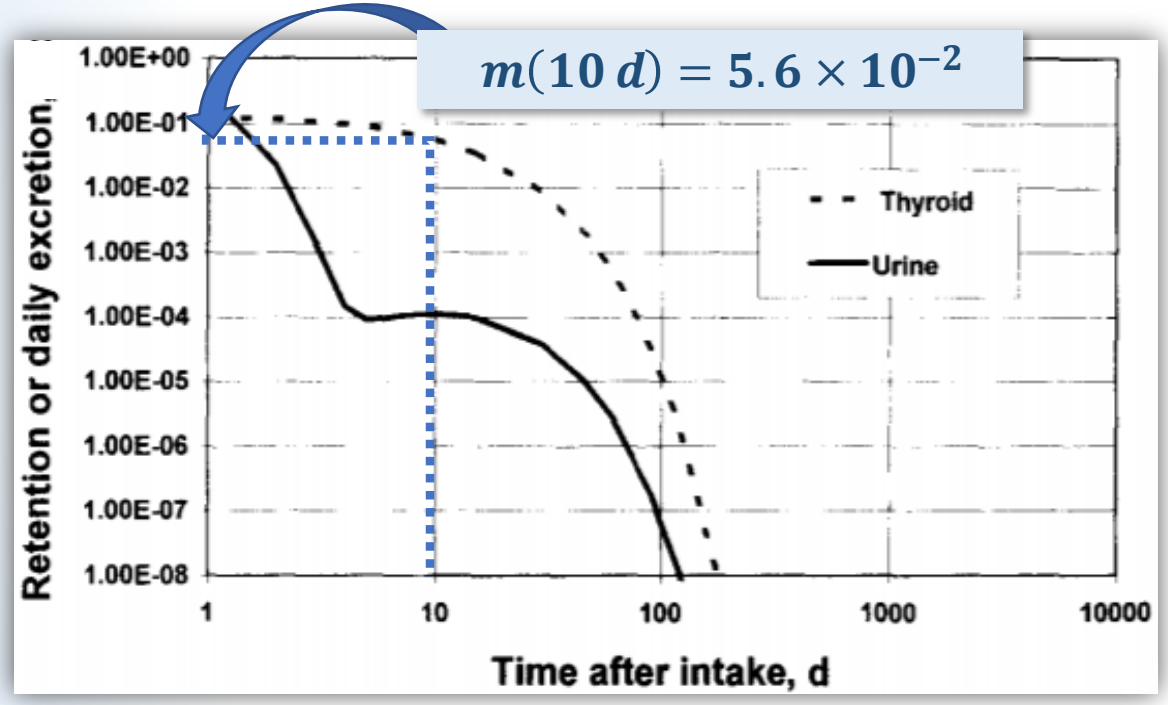
Thyroid counting. Courtesy of Internal Dosimetry Laboratory, CNEA_National University of Asuncion (Paraguay)



I-131 Inhalation Type F: predicted values **(Bq per Bq intake)** following acute intake, ICRP 78 (1997)

Assessment of dose from measurements

***m*(*t*)** : **fraction of an intake that remains in the body** (for direct methods**)** or that is being **excreted from the body** (for indirect methods) at **time *t* after the intake.** This fraction depends on the radionuclide, its chemical and physical form, the route of intake and the time *t*.



I-131 Inhalation Type F: predicted values **(Bq per Bq intake)** following acute intake, ICRP 78 (1997)

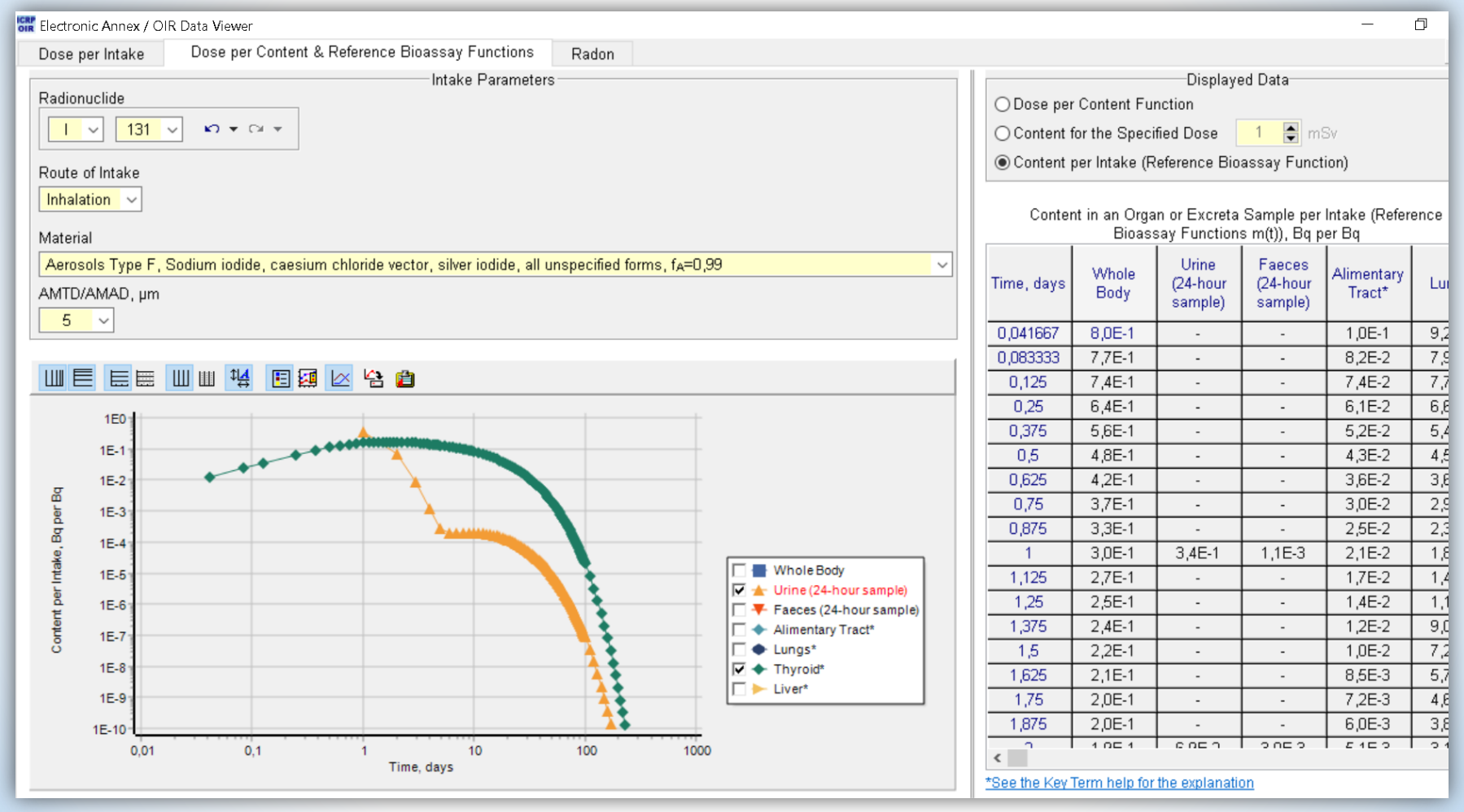
If t is known: $$I = \frac{M}{m(t)}$$

Routine monitorings: $$I = \frac{M}{m(T/2)}$$

midpoint of the monitoring period T

Free ICRP's Data Viewer

for radionuclides from the **OIR parts 2, 3, and 4** (When published, the electronic supplement to OIR Part 5 will supersede it)



The data viewer can display dose per intake, dose per content functions, content for specified doses, and content per intake (Reference Bioassay Functions).

Software for internal dosimetry

DCAL

IMBA

AIDE

MONDAL

PLEIADES

IDEA system

IDSS

New Models and Coefficients:

IDEAplus Expert System

TAURUS

Assessment of dose from measurements

- If no special information is available, the following default parameter values could be used:
  - **Mode of intake:** Single intake (inhalation)
  - **Time of intake:** Mid-point of the monitoring interval

$$I = \frac{M}{m(T/2)}$$

Inhalation:

- **Absorption Type and f_1 value:** defaults according to ICRP publications.
- **Particle size**: 5 μm AMAD

Ingestion:

- **f_1 value:** defaults according to ICRP

Effective dose = I× e(g)

For routine monitoring if the exposure is likely to be very low with respect to the dose limits, the default parameters set out in GSR Part 3 may be sufficient for assessing the intakes.

- If the monitoring values indicate the exposure to be **close to or even above the dose limits**, more sophisticated evaluation procedures will need to be applied.

IDEAS Guidelines,
EURADOS Report 2013-01
C.M. Castellani, J.W. Marsh, C. Hurtgen, E. Blanchardon, P. Berard, A. Giussani, M.A. Lopez

Spanish version

Reference values

For work involving risk of internal exposure, a level of activity concentration in air or intake of activity into the body may need to be established **to be used as an indication of whether there is the potential for a significant individual exposure**

Investigation level:

Value of a quantity which an investigation would be conducted. For instance:

$$IL_j = \frac{0.005}{N \cdot e(g)_j}$$

Recording level:

Is a level of dose, exposure or intake specified by the regulatory body at, or above, which values of dose to, exposure of, or intake by workers are to be entered into their individual exposure records. For instance:

$$RL_j = \frac{0.001}{N \cdot e(g)_j}$$

Monitoring Interval

How to chose the long of the monitoring intervals? Typically, the frequency of monitoring should be such as to ensure that intakes corresponding to more than 5% of the annual dose limit can be detected.

Information on the **detection limit** for a particular measurement technique is used to determine a monitoring interval appropriate for the dose level of interest. Because an intake I and the resulting **committed effective dose** E(50) **would be missed if the product I × m(t) were less than the detection limit.**

Maximum values of recommended monitoring intervals for various radionuclides and various measurement techniques are given in ISO 27048:2011, IDEAS Guidelines (Version 2)

Radionuclide	Absorption type	Maximum time interval (days)
^{51}Cr	F	15
^{54}Mn	M	90
^{59}Fe	M	90
^{57}Co	S	180
^{58}Co	S	180
^{60}Co	S	180
^{75}Se	M	180
^{110m}Ag	S	180
^{137}Cs	F	180

Whole body measurements

Radionuclide	Absorption type	Maximum time interval (days)
^{125}I	F	90
^{131}I	F	15

Thyroid measurements

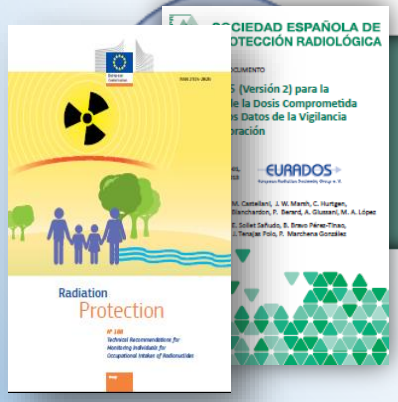
Part of tables 3.8 and 3.10, IDEAS Guidelines (versión 2)

Challenges of monitoring of medical workers

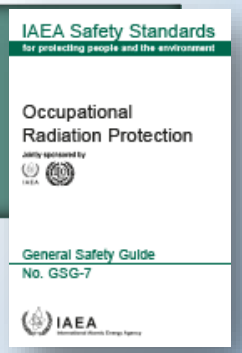
CURRENT SITUATION: **Surveillance Of Occupational Internal Exposure In Nuclear Medicine Centres**

Increase in the use of Radiopharmaceuticals in Nuclear Medicine; need for "in situ" control of internal exposure

Publications dedicated to occupational radiological protection in medical practice: **ISO 16637 *"Radiological protection --Monitoring and internal dosimetry for staff exposed to medical radionuclides as unsealed sources"***



New specific documents related to internal occupational dosimetry : GSG-7, TECHREC Nº188, IDEAS Guidelines



Challenges of monitoring of medical workers- Harmonized guidelines

INTERNAL DOSIMETRY

Action Plan in Nuclear Medicine

Development of a guideline focus on the calibration process of **available detection systems in NMCs**

Development of an occupational guideline for direct measuring of ^{131}I in thyroids for control internal exposure "in situ" of workers.

Development of an occupational guideline for establishing a monitoring plan and occupational dose assessment

Implementation of a pilot program for occupational monitoring of internal exposure to ^{131}I in NMCs

Organization of a Regional intercomparison for dose calculation

Nuclear Medicine (2020- 2021)

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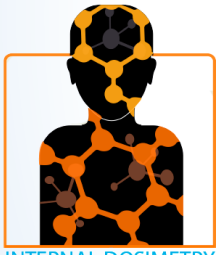
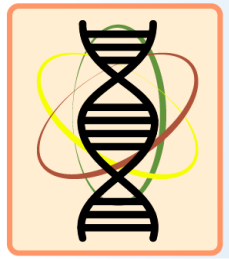
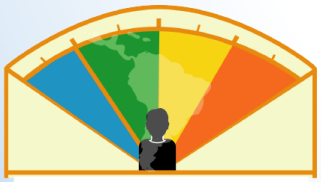
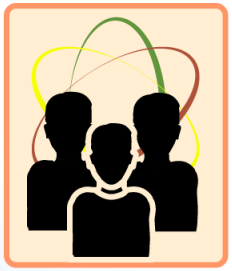

INTERNAL DOSIMETRY


COMPUTACIONAL DOSIMETRY


EXTERNAL DOSIMETRY


BIOLOGICAL DOSIMETRY


METROLOGY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