Main characteristics of the Human Respiratory Tract Model (HRTM) used in the OIR and EIR series

TG 95 Webinar
Internal Dose Coefficients for Workers and Members of the Public
6 December 2023

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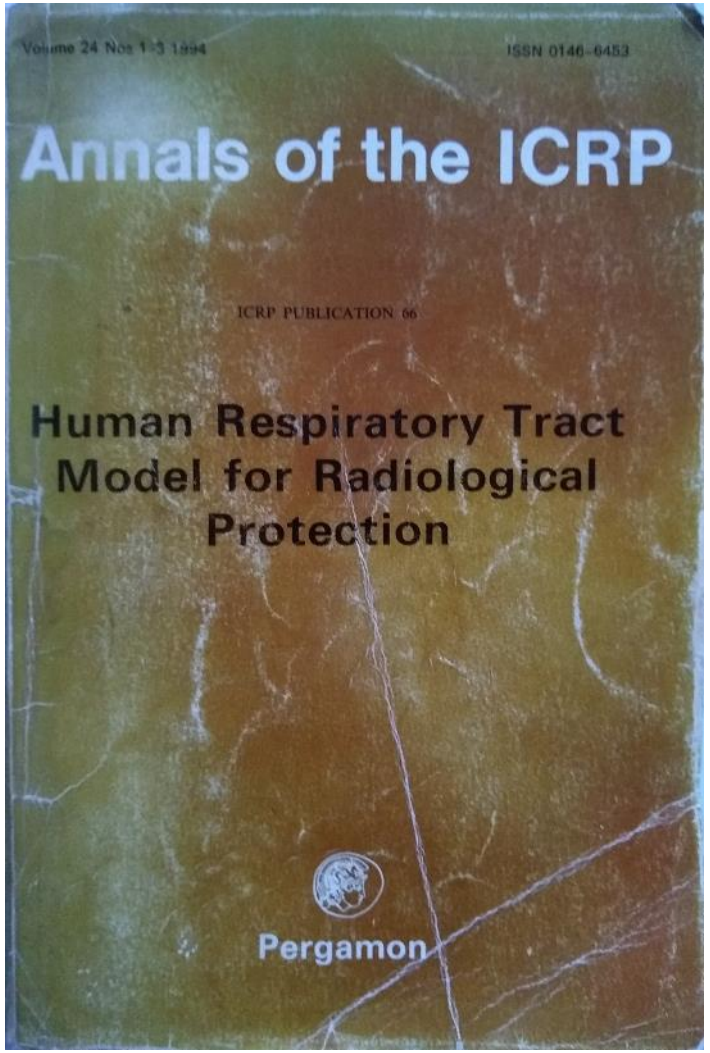
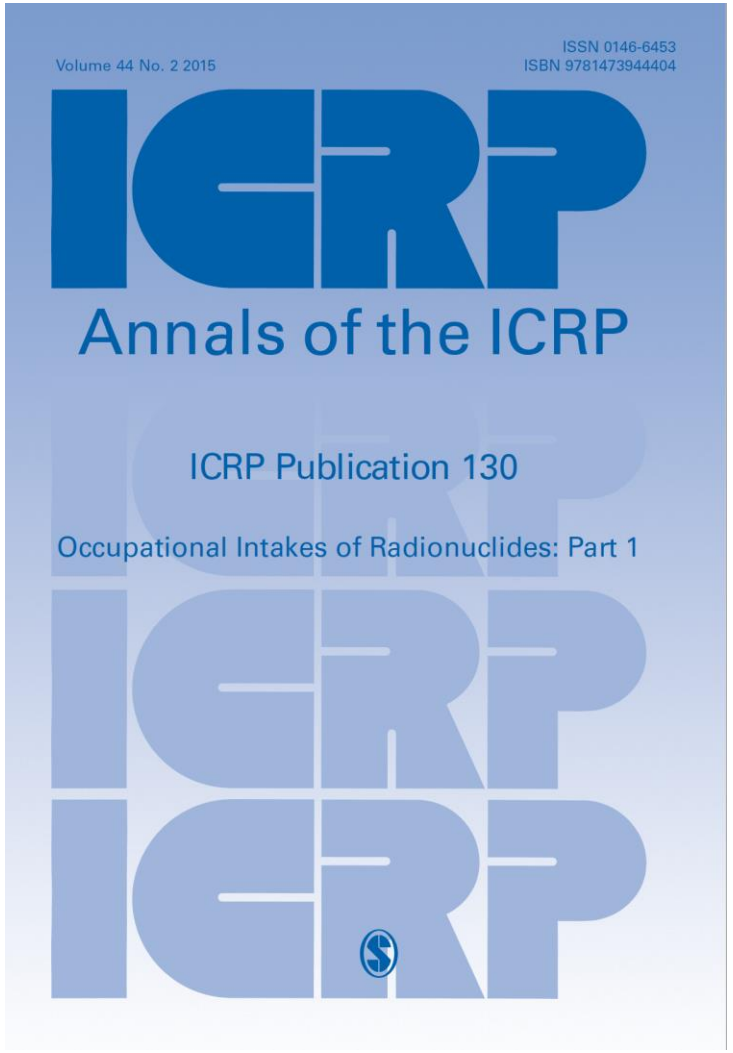
ICRP

Revision of the Human Respiratory Tract Model (HRTM)

ICRP 66 (1994)





ICRP 130 (2015) Annex A

Scope of the HRTM

HRTM: Quantitative description of the respiratory tract as a route of entry of radionuclides to the body.

- Calculating activity distribution and retention in RT regions (lungs monitoring)
- Calculating doses to RT target tissues (absorbed and equivalent doses)
- Aerosol particle sizes 0.001 – 20 μm, gases and vapours
- For workers and members of the public. One Reference Individual for each age-group:

  3-months, 1-, 5-, 10- and 15-y old children and adult (worker and public).

Respiratory tract regions

Extrathoracic airways

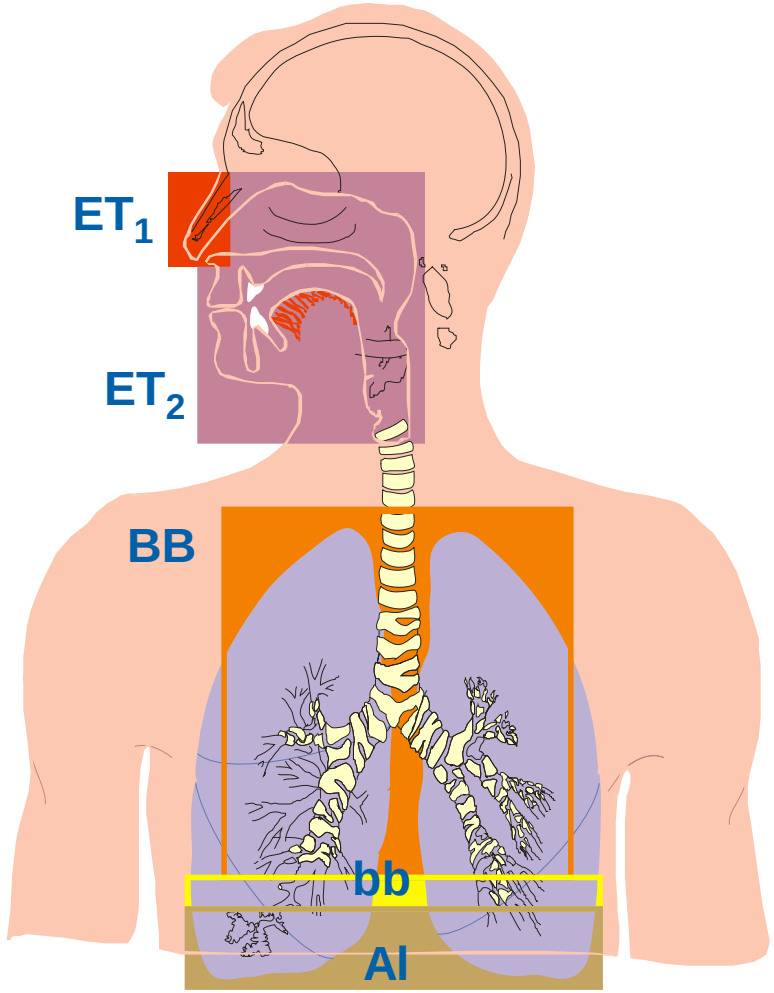
ET_1: anterior nasal passages

ET_2: posterior nasal passages, pharynx and larynx

Bronchial

Bronchiolar

Alveolar interstitial



Particle deposition in respiratory tract

Total and regional deposition

fraction(s) of the intake deposited in the respiratory tract (regions)

Anatomical and physiological parameters

- dimensions of respiratory tract
- ventilation rate, breathing frequency
- fraction breathed through nose

Aerosol parameters

- particle size distribution (AMAD or AMTD, σ_g)
- particle density and shape factor

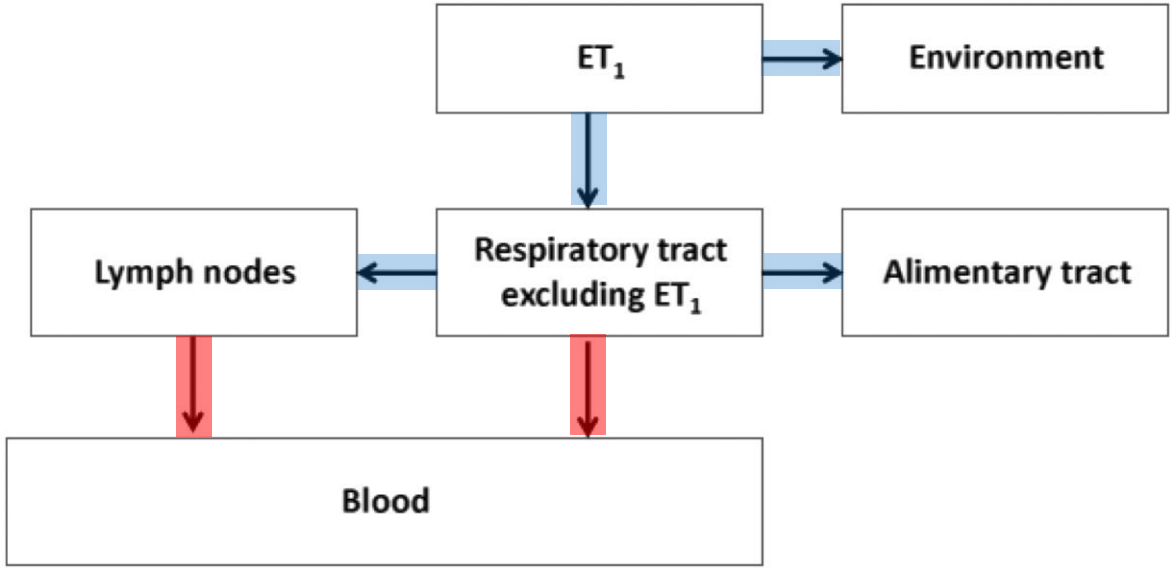
Exposure	AMAD (μm)
Occupational	5
Environmental	1

Exception: short-lived progeny of radon (ICRP137, OIR P3)

Clearance model for the respiratory tract

Simplifying modelling assumptions

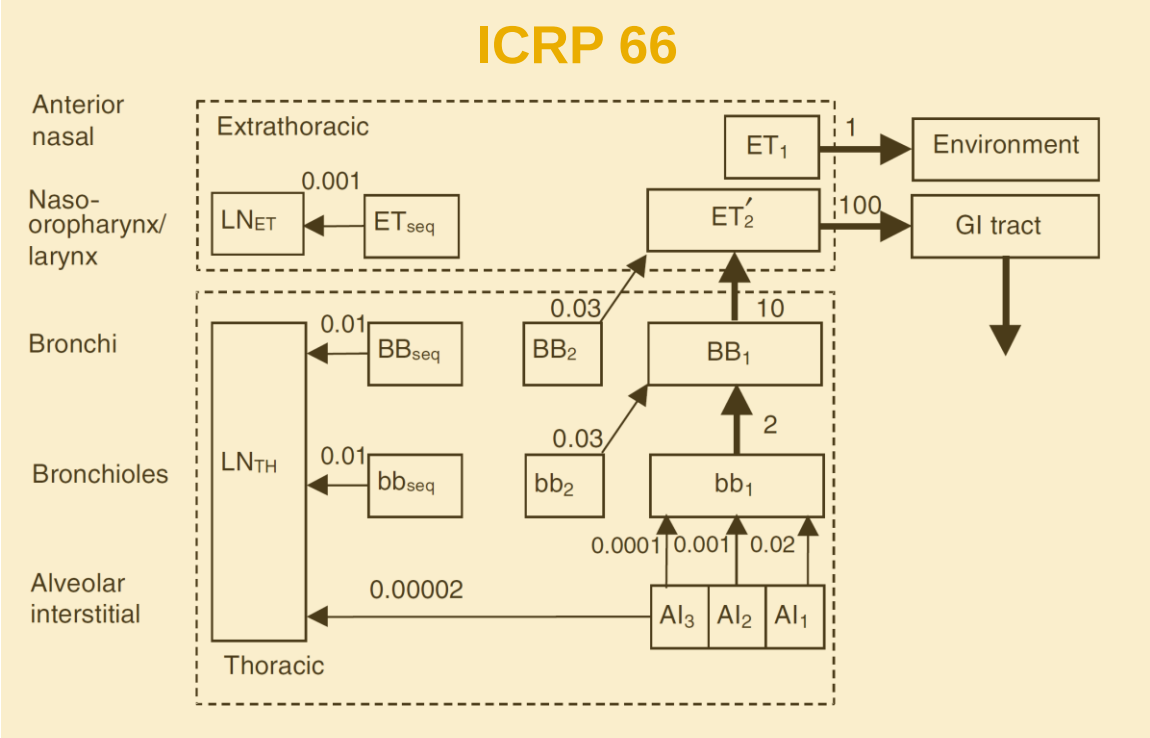
- Two independent mechanisms:
  - **particle transport**
  - **absorption into blood**
- Independent of age and sex
- Particle transport same for all materials
- Absorption same in all regions except ET1
- Compartmental model with constant rates

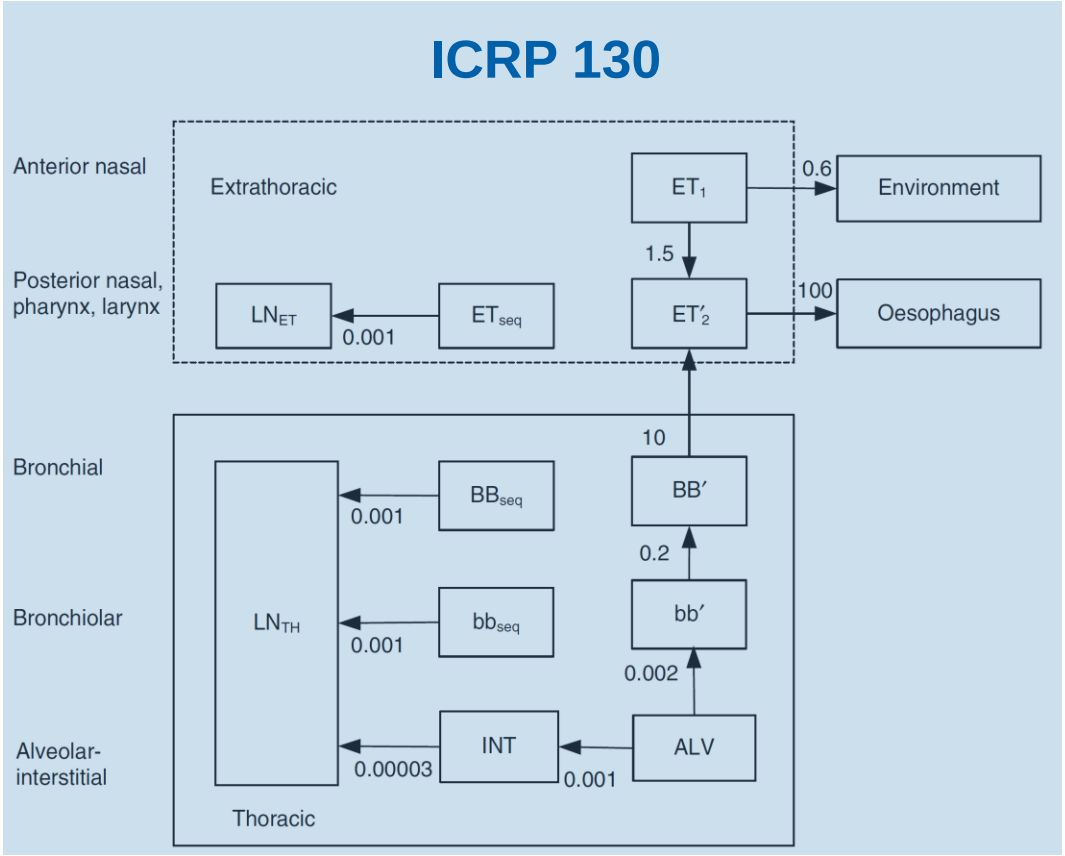


Clearance by particle transport

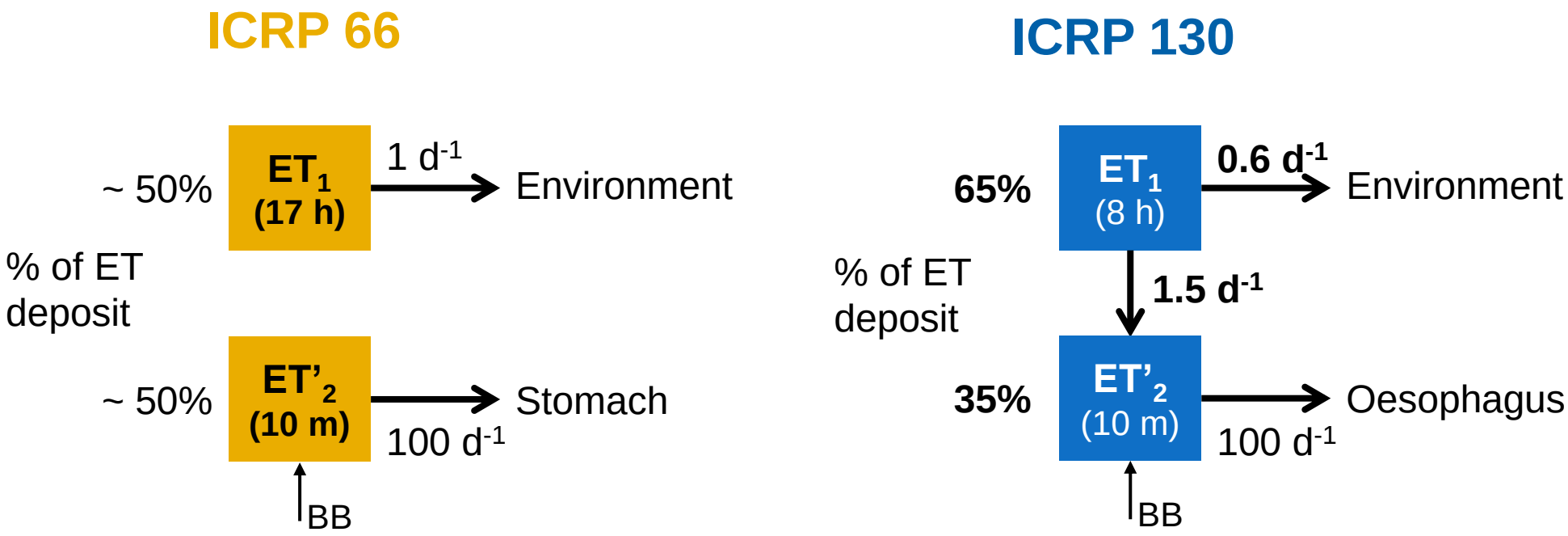
Revision of particle transport

- Simplified model structure
- changes to transport rates (d^{-1})





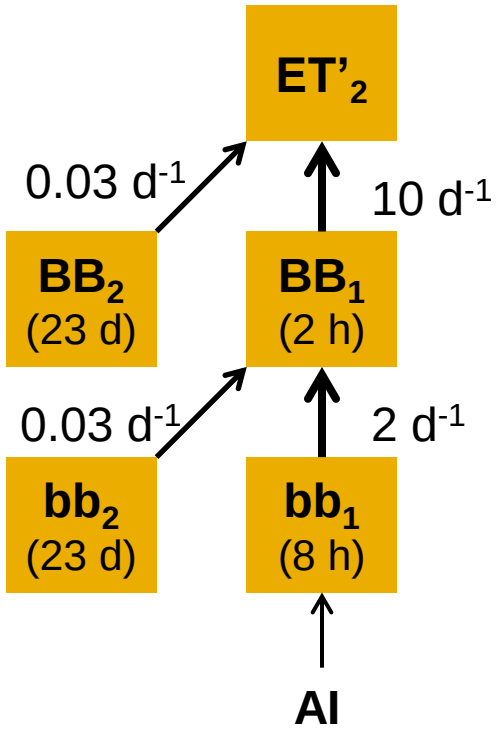
Clearance by particle transport: Extra-thoracic regions



- May increase dose coefficients
  - greater systemic uptake from ET_2 and alimentary tract
- Monitoring of faecal samples:
  - increased clearance to alimentary tract (~ 80% ET deposit)

Clearance by particle transport: Bronchial and bronchiolar regions

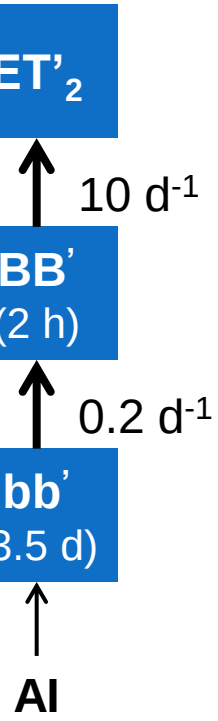
ICRP 66



ICRP 130

No slow clearance in BB

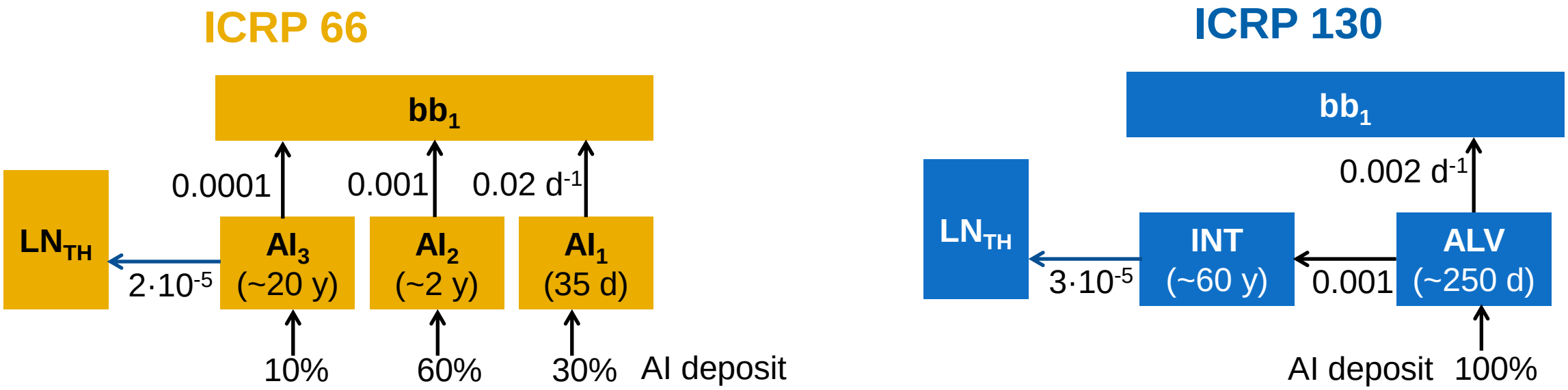
Slow clearance only in bb



Decreased lung dose

for moderately soluble materials of alpha emitters with radioactive half-lives of weeks or more

Clearance by particle transport: alveolar-interstitial region



- Greater retention in AI region for insoluble particles
- About 33% of the alveolar deposit is sequestered in the interstitium (for insoluble particles)
- Lung doses 50–100% higher for insoluble materials of long-lived α-emitters, little effect on more soluble forms.

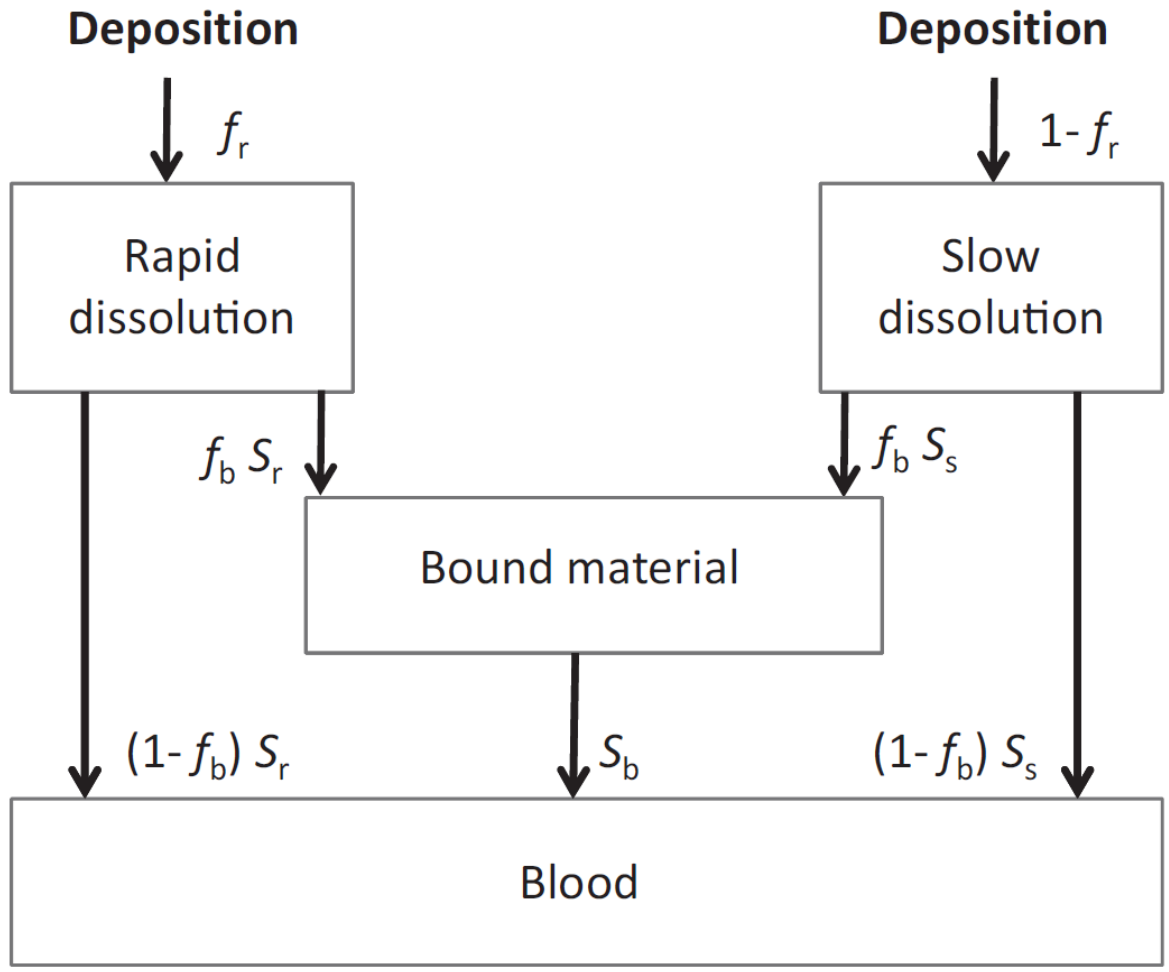
Clearance: absorption into blood

Depends on the physical and chemical form

Same rates in each RT regions, except ET_1

Two stages: dissolution + uptake to blood

Bound material not subject to particle transport



Clearance: absorption into blood

Review of experimental data (in vitro, in-vivo)
to derive absorption characteristics of inhaled materials

- update default values for three types of materials:
  Type F (fast), M (moderate) and S (slow)

  Where sufficient information (limited set) adopt
- material-specific values
- element-specific values for bound state
- element-specific values for rapid absorption rate in soluble materials

Clearance by absorption to blood: default Types (F,M,S)

Absorption Type		ICRP 66 F (fast)	ICRP 66 M (moderate)	ICRP 66 S (slow)	ICRP 130 F (fast)	ICRP 130 M (moderate)	ICRP 130 S (slow)
Fraction dissolved rapidly	f_r	1	0.1	0.001	1	0.2	0.01
Rapid dissolution rate (d^{-1})	s_r	100	100	100	30	3	3
Slow dissolution rate (d^{-1})	s_s	-	0.005	0.0001	-	0.005	0.0001

Bound state not included in default types F, M and S

Changes to f_r and s_r values
reduce rapid absorption in the ET airways and increase in the lungs.

Deposition and clearance of gases and vapours

The ICRP-66 classification **SR-0, SR-1, SR-2** not been found helpful and no longer used.

Type V (very fast): Instantaneous uptake into blood has also been recommended.

Revised default
100% deposition and Type F absorption.

Deposition (%)

	Default		HTO	I_2	Hg
Tot	100		100	100	80
ET1	0		0	0	0
ET2	20		20	50	2
BB	10		10	50	1
bb	20		20	0	2
AI	50		50	0	75
Type	F		V	F	F

Revised HRTM

Description of the revised HRTM model in

- ICRP Publication 130, OIR Part 1, Introduction and **Annex A**.
- ICRP Publication xxx, EIR Part 1, Introduction

Absorption parameter values for each element

- OIR Part 2-5
- EIR Part 1-3

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Thank you.

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Absorption to blood: element-specific parameters

Rapid absorption rate, soluble forms (Type F)

s_r	Elements
100	H, C, Fe,Tc, I, Cs, Pb
70	Ca
50	Te, Th, Pa
20	Ba
10	Ra, U
3	Po, Ni
1	P, Co, Y, Bi, Ag, all lanthanoids
0.4	Ac, Pu, all trans-plutonium

s_r values also used for Type M and S if less than 3 d^{-1}.

Bound fraction and uptake rate

	f_b	s_b (d^{-1})		ET_2	BB, bb	AI
Co	0.03	0.002				x
Ru	0.05	0.1		x	x	x
Ce*	0.07	0.02		x		x
Hg	0.24	2.1		x	x	x
Pb	0.5	1.7		x	x	x
Pu*	0.002	0.		x	x	x

Applied to conducting airways (ET2, BB and bb) **only if** supporting experimental evidence (autoradiography, autopsy data).