

Dose conversion factors for radon



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HEIR, New Mexico, May 2009

Draft report of Radon statement

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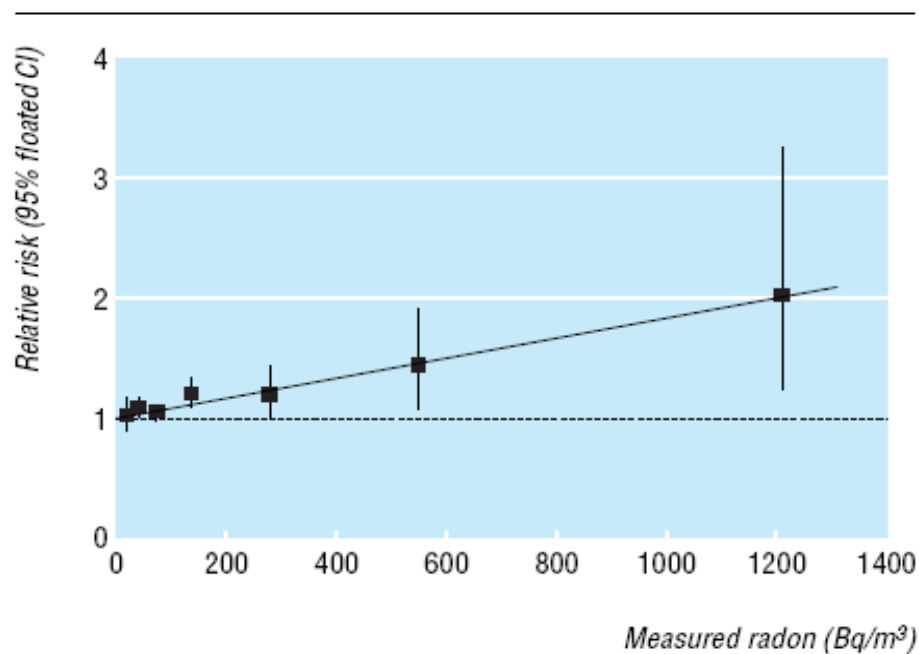
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- Epidemiological studies
 - Residential studies
 - Miner studies
- Dose conversions factors
 - *Epidemiological approach*
 - Dosimetry approach
- ICRP upper reference levels

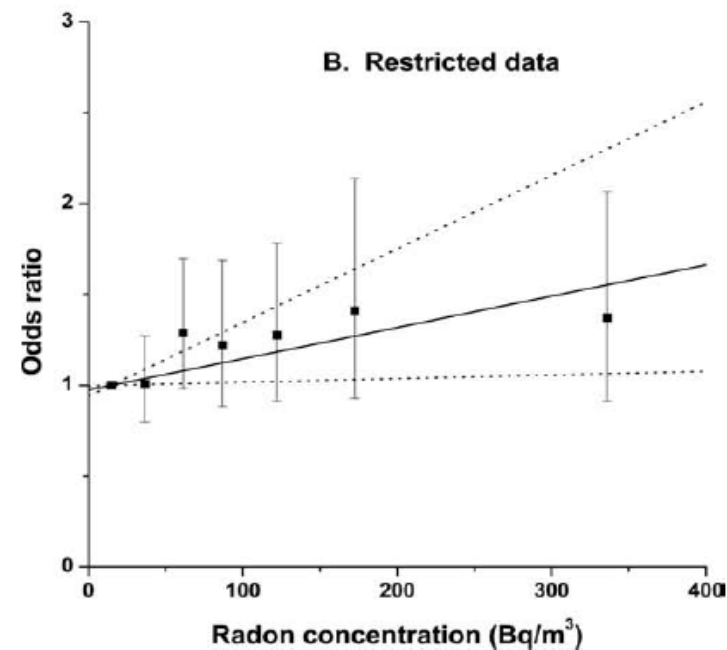
- The 3 main studies of residential radon are the joint analyses of European, North American and Chinese studies.
- Risk of lung cancer is increasing with cumulated exposure to radon decay products
 - risk exists at levels $< 200 \text{ Bq/m}^3$
- RR increases by about 10% per 100 Bq/m^3 increase. A 25 year exposure period was considered.
 - if uncertainty linked to past exposure is taken into account, then this risk coefficient is higher in most studies
- Absolute risk for smokers is about 25 times greater compared with lifelong non smokers

Europe



Darby et al **2005**

North America



Krewski et al **2005**

Miner data - Lifetime Excess Absolute Risk (LEAR)



Reference	Model	Background	Risk x 10^{-4} WLM $^{-1}$
ICRP (1993)	Pub 65 (GSF)	Pub 60, M+F	2.83
EPA (2003)	BEIR VI ^(a)	USA	5.4
Tomasek (2008)	Pub 65	Pub 103, M+F	2.7
	BEIR VI ^(b)	Pub 103, M+F	5.3
	Czech-French	Pub 103, M+F	4.4

(a) Combination of the 2 BEIR VI risk models

(b) Exposure-age-concentration risk model

A lifetime excess absolute risk of $5 \cdot 10^{-4}$ per WLM is proposed for radiation protection purposes.

Epidemiological approach: Dose conversion convention (Effective dose per unit exposure)



ICRP Pub 65 (1993)

Lung cancer risk in mines: 2.83×10^{-4} per WLM (lung mortality)

ICRP Pub 60 (1991):

Total detriment per unit effective dose: 5.6×10^{-2} per Sv (worker)

Equating total detriment we obtain:

$$\begin{aligned} \text{Effective dose per WLM} &= \frac{\text{detriment per unit exposure}}{\text{detriment per unit effective dose}} \\ &= \frac{2.83 \times 10^{-4}}{5.6 \times 10^{-2}} = 5.05 \text{ mSv per WLM for workers} \end{aligned}$$

Dose conversion convention

(Effective dose per unit exposure)

ICRP Pub 65 (1993) dose conversion convention

Compare lung cancer risk in miners

2.83×10^{-4} per WLM

with total detriment from cancer and hereditary effects from Pub 60 (1991):

Workers	5.6×10^{-2} per Sv	5 mSv per WLM
Public	7.3×10^{-2} per Sv	4 mSv per WLM

Publication 60 / 103 detriment $\times 10^{-2}$ per Sv



Publication 60 (1991)

	Cancer		Hereditary	Total
	Lung	Total		
Worker	0.6	4.8	0.8	5.6
Public	0.8	6.0	1.3	7.3

Publication 103 (2007)

Worker	1.2	4.1	0.1	4.2
Public	0.9	5.5	0.2	5.7

Dose conversion convention (Effective dose per unit exposure)



Updated values

USE revised value of 5×10^{-4} per WLM for the lung cancer risk

Equating total detriment using ICRP Publication 103 values

Workers	$4.2 \times 10^{-2} \text{ Sv}^{-1}$	12 mSv WLM ⁻¹
Public	$5.7 \times 10^{-2} \text{ Sv}^{-1}$	9 mSv WLM ⁻¹

Current ICRP values

ICRP 65 value: 2.8×10^{-4} per WLM (lung cancer risk)

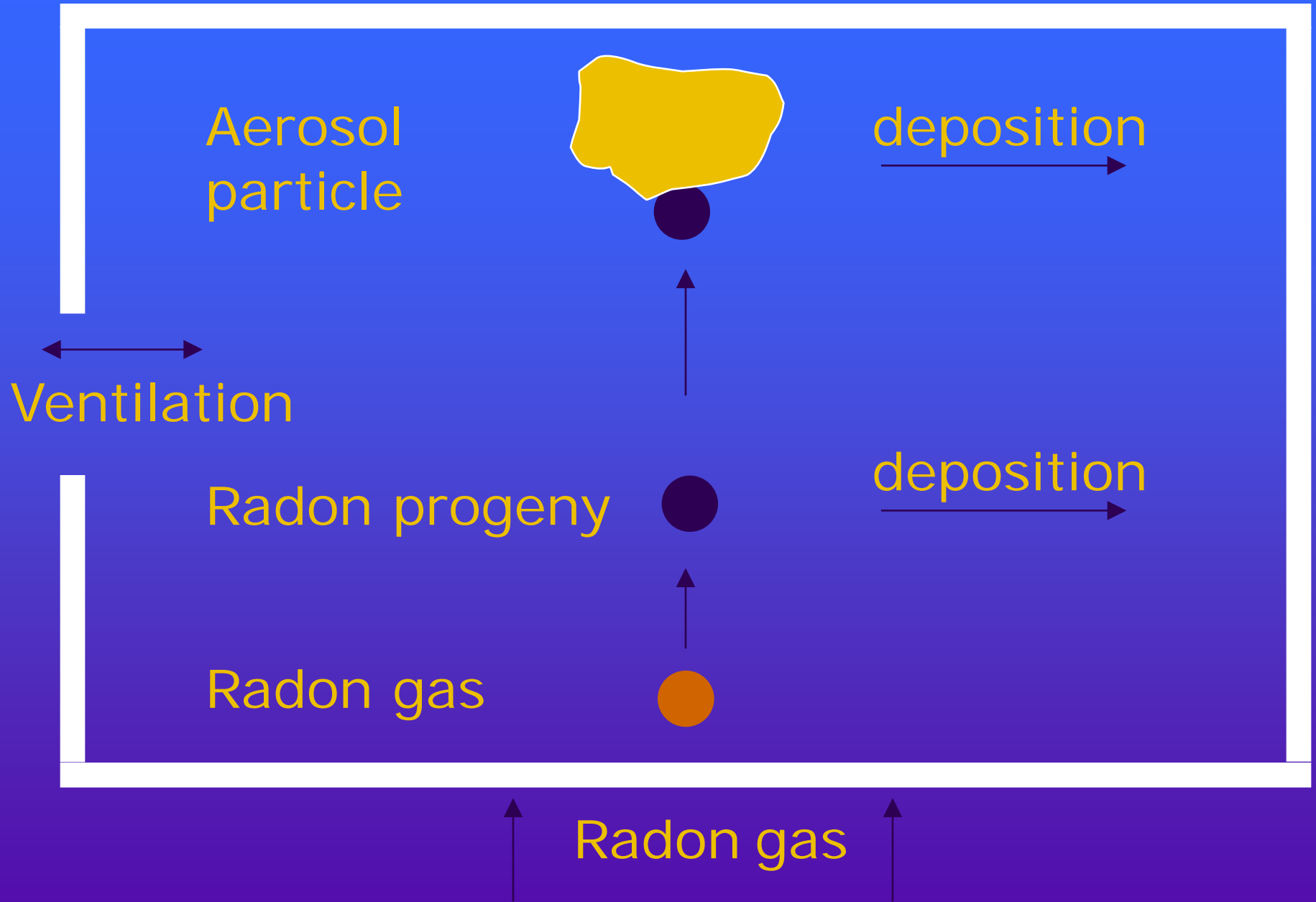
Equating total detriment using ICRP Publication 60 values

Workers	$5.6 \times 10^{-2} \text{ Sv}^{-1}$	5 mSv WLM ⁻¹
Public	$7.3 \times 10^{-2} \text{ Sv}^{-1}$	4 mSv WLM ⁻¹

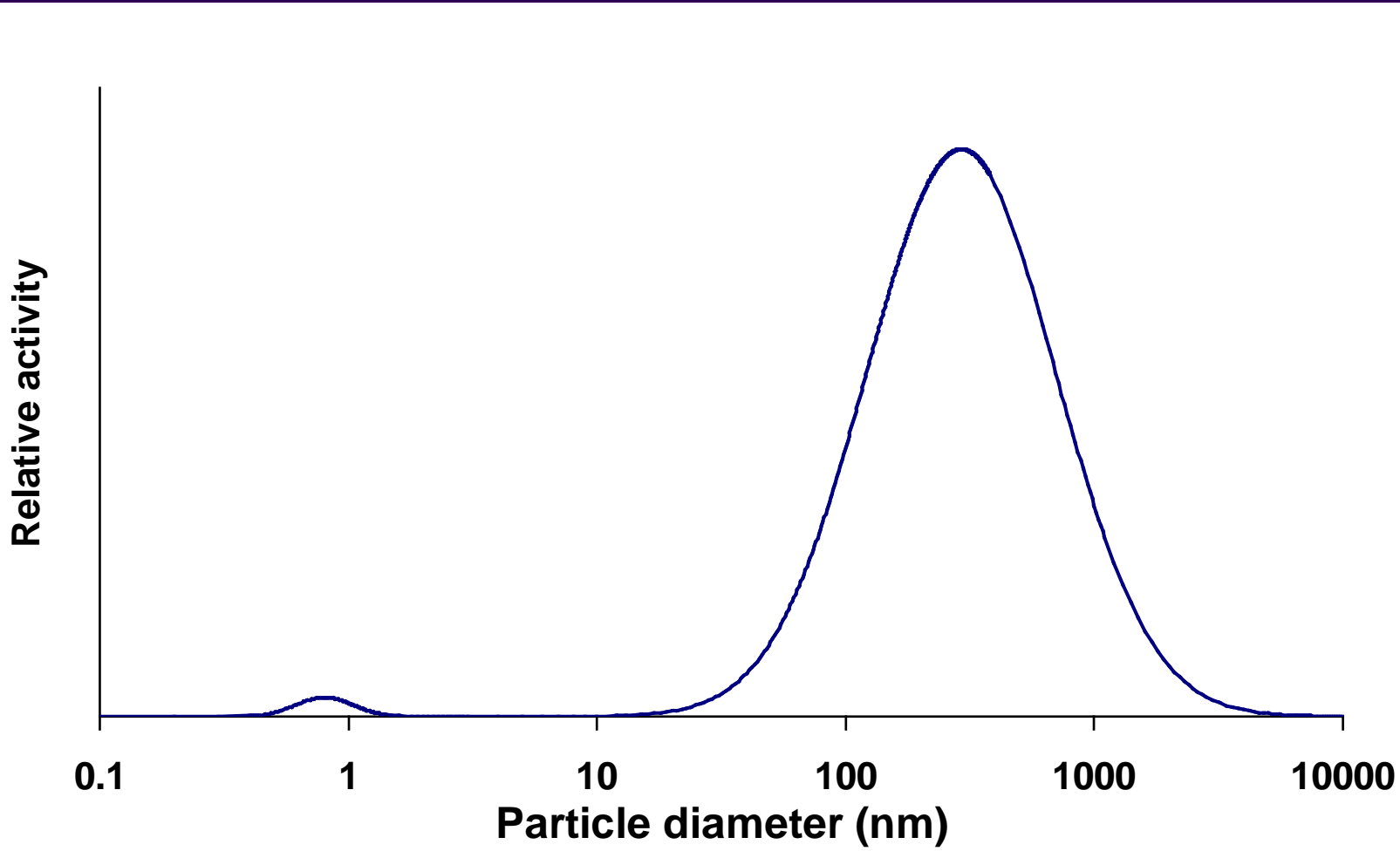
Decay chain

Radon gas	^{222}Rn	3.8 d
	↓	
Polonium	^{218}Po	3 min
	↓ α	
Lead	^{214}Pb	27 min
	↓	
Bismuth	^{214}Bi	20 min
	↓	
	^{214}Po	160 μs
	↓ α	
	^{210}Pb	22 y

Formation of radon progeny aerosol

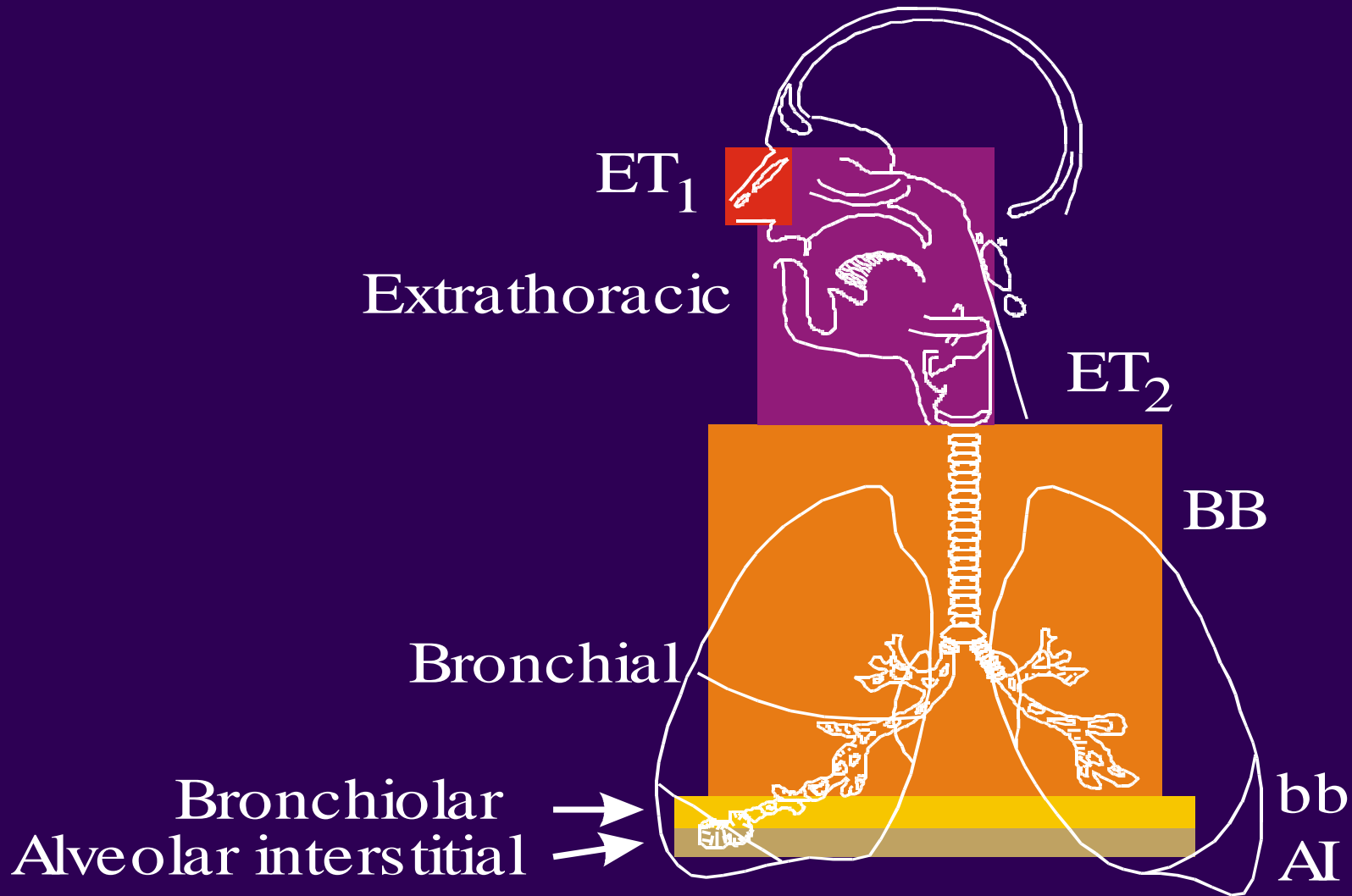


Activity size distribution of a radon progeny aerosol in a mine

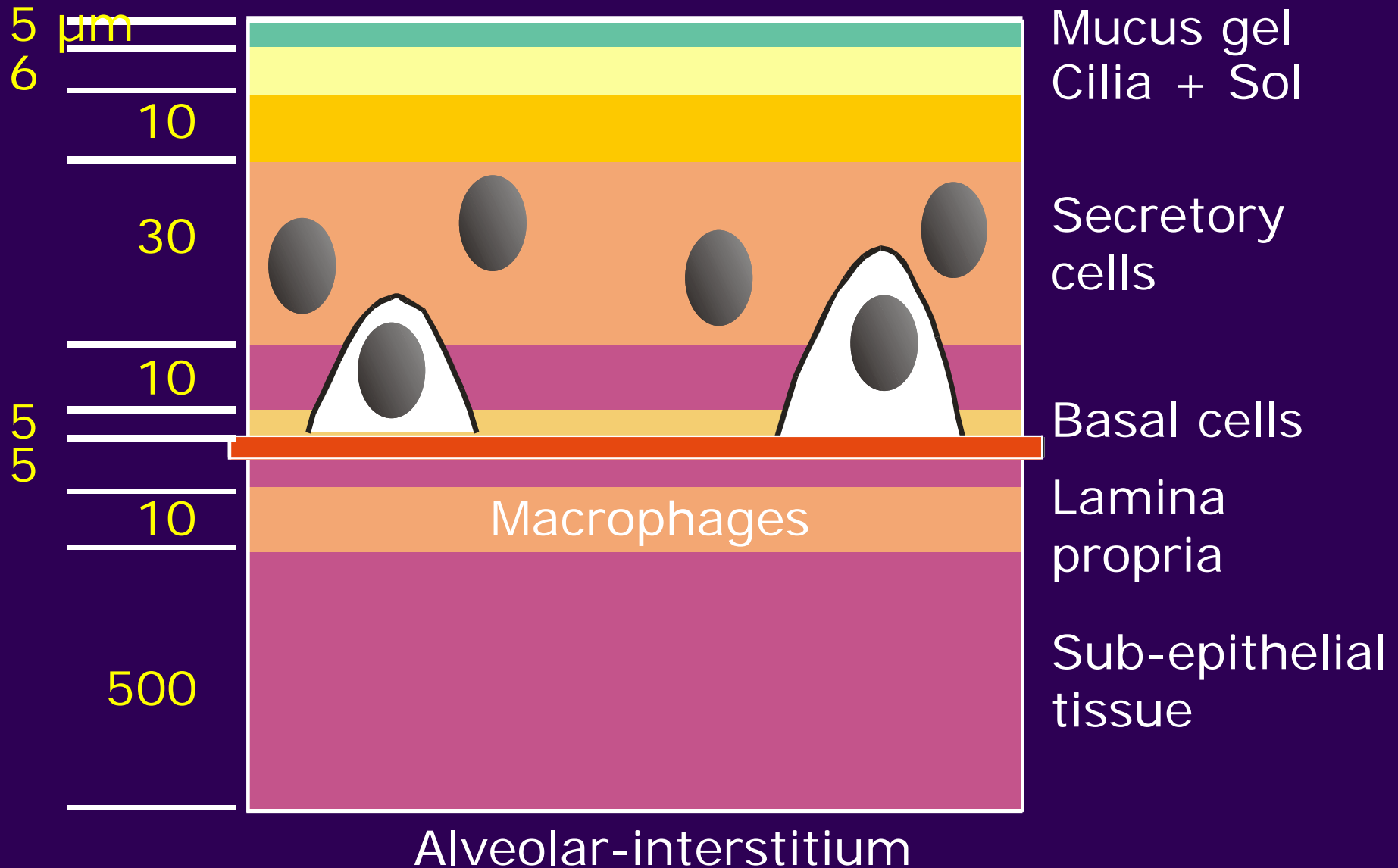


Human Respiratory Tract Model (HRTM), ICRP Pub. 66

Respiratory Tract Regions



Bronchial (BB) Wall for Dosimetry



Equivalent dose to lung, H_{lung}

Equivalent dose is calculated to each of the 3 regions:

- $H_{\text{BB}} = \frac{1}{2} H_{\text{bas}} + \frac{1}{2} H_{\text{sec}}$ (bronchial region; airway generations 1-8)
- H_{bb} (bronchiolar region; airway generations 9 - 15)
- H_{AI} (Alveolar- Interstitial region)

$$H_{\text{lung}} = 0.333 H_{\text{BB}} + 0.333 H_{\text{bb}} + 0.333 H_{\text{AI}}$$

Effective dose to a miner is about

13 mSv WLM^{-1}

Region	Absorbed dose (mGy WLM^{-1})	Equivalent dose (mSv WLM^{-1})
BB basal cells (D_{bas})	5.6	
bb secretory cells (D_{sec})	12.6	
BB $\frac{1}{2}(D_{\text{bas}} + D_{\text{sec}})$	9.1	183
bb	6.1	122
AI	0.4	7
Lung		104

		Effective dose mSv per WLM
ICRP, 1994	Marsh & Birchall, 2000 James et al, 2004 Marsh et al, 2005	15 (home) 21 (mine, home) 13 (mine, home)
NEA, 1983	ICRP, 1987 UNSCEAR, 2000	6 (indoor) 9 (outdoor) 6 (indoor/outdoor)
	Winkler-Heil et al, 2002	Mine
Deterministic airway generation model		8
Stochastic airway generation model		9
HRTM		12

Effective dose per WLM

Dosimetry, with HRTM:

Mines & Homes: 13 mSv WLM⁻¹ Marsh et al. 2005

Epidemiological approach:

Worker: 12 mSv WLM⁻¹ , Public: 9 mSv WLM⁻¹

Good agreement

It is proposed, for radiation protection purposes to calculate doses using the HRTM.

Upper Reference Levels

	Occupancy (hours per year)	Upper reference levels		
		Current (a)	Possible	
		y Bq m ⁻³	y Bq m ⁻³	WLM (b)
Home	7000	600	300	1.3
Work	2000	1500	800	1.0

(a) ICRP Publication 103.

(b) Equilibrium factor, F=0.4

- The doubling of the estimated lung cancer risks indicate that the reference levels could be approximately halved.

Upper Reference Levels (y Bq m⁻³)



	Current	Possible	
Home	600	300	} No final decision
Work	1500	800	

- As a result of optimisation national authorities should set lower levels taking account of economic and societal circumstances.
- Doses from radon exposures above the reference level should be considered as part of occupational exposures.
- Exposures below reference levels should be regarded as a component of natural exposure.
- It is proposed, for radiation protection purposes, to calculate doses using the HRTM.

Main points

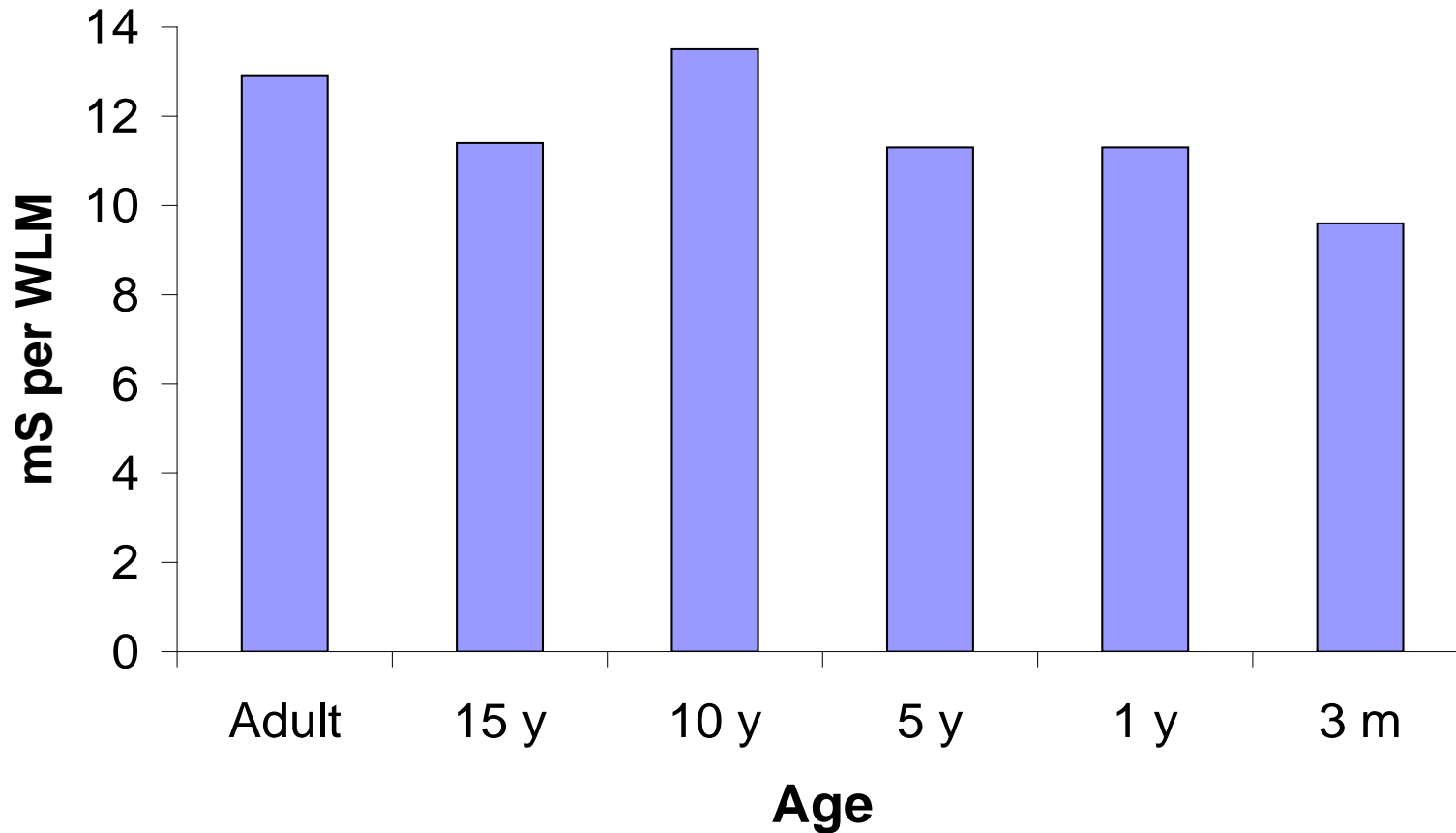
- Residential radon risk demonstrated to $< 200 \text{ Bq} / \text{m}^3$
- The absolute risk for current smokers is about 25 times greater than for lifelong non-smokers
- Revised lung cancer risk estimates based on miner data of 5×10^{-4} per WLM
- Risk management in homes on the basis of exposure to radon gas.
- Possible reduction of upper reference levels to:
 - $300 \text{ Bq} / \text{m}^3$ for homes (annual)
 - $800 \text{ Bq} / \text{m}^3$ for work (annual)
- For radiation protection purposes use HRTM to calculate doses

No final
decision



Thank you for your attention

Sensitivity of effective dose with age, (Marsh, 2005)



Competing effects that tend to cancel out, for example:

- Children have lower breathing rates so this decreases intake for a given exposure
 - Partly compensated by smaller target tissues

Frequency Distribution of Effective Dose per WLM in the Home



**Geometric mean, GM
= 13 mSv per WLM**

GSD = 1.7