Current and forthcoming ICRP recommendations on radon exposure

International Conference on Occupational Radiation Protection

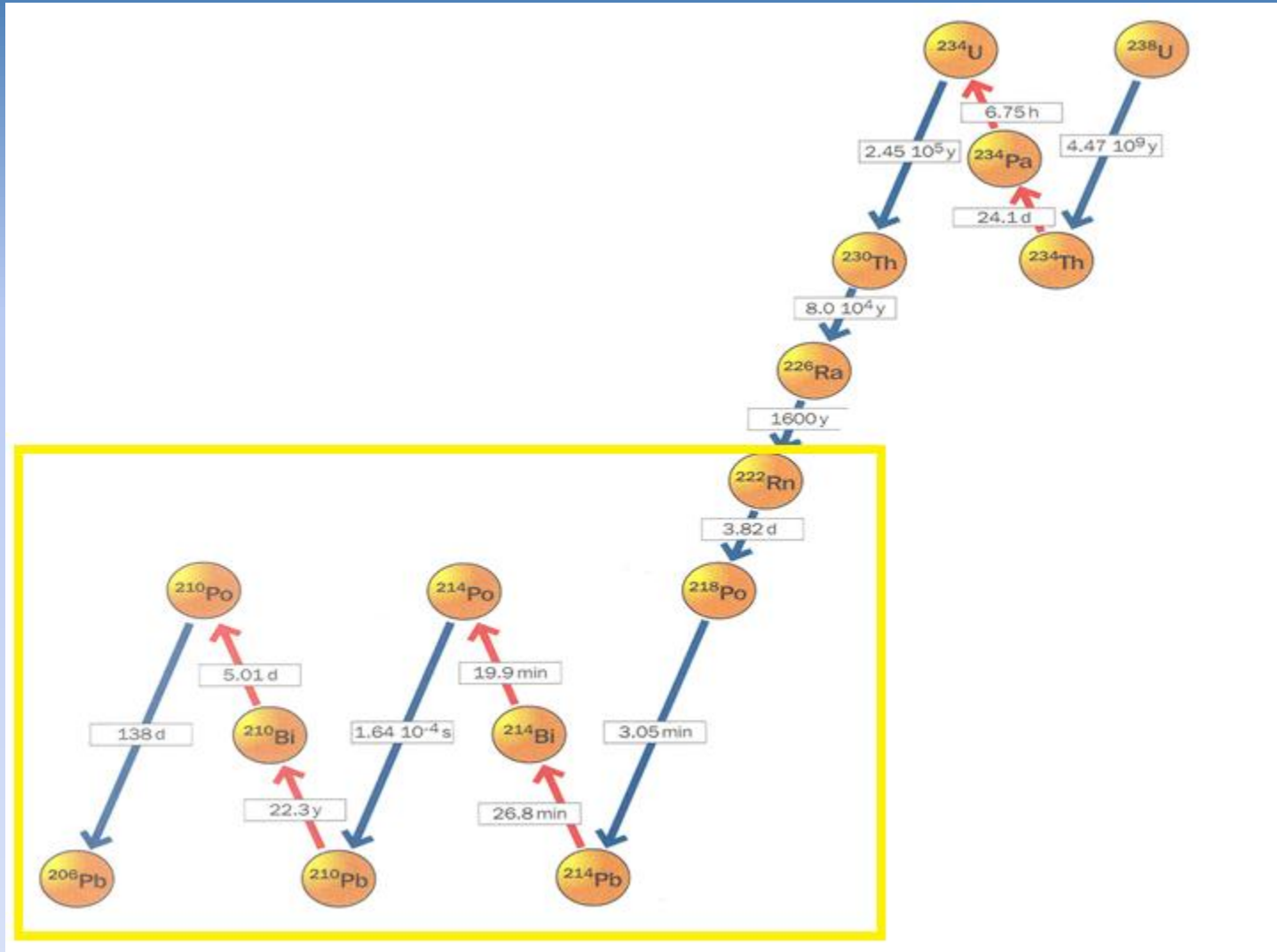
Occupational radiation protection in the workplace involving exposure to radon

John Hunt for John Harrison
Public Health England

Topics – exposure to ^{222}Rn

- Epidemiological studies
  - Homes
  - Mines
- Dose coefficients, Sv per unit exposure
  - Epidemiological approach
  - Dosimetric approach
- ICRP reference levels

Radon-222 in the Uranium-238 decay chain

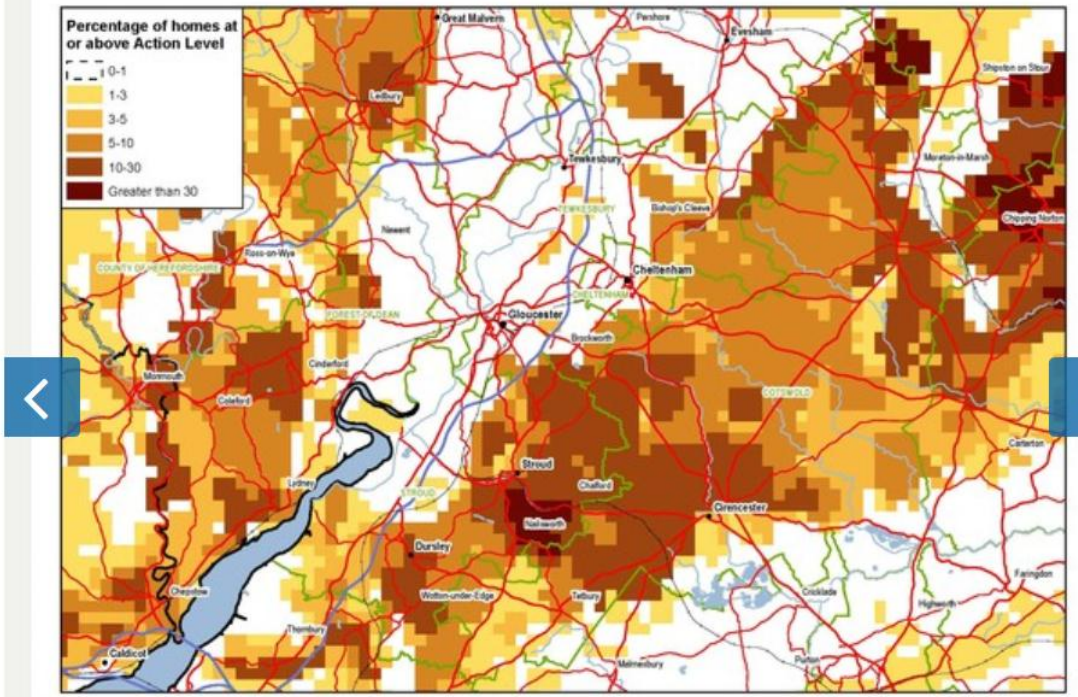


Gloucestershire Echo, November 2014

Action level = 200 Bq/m^3

Public Health England to scan thousands of homes in Gloucestershire for radioactive gas radon

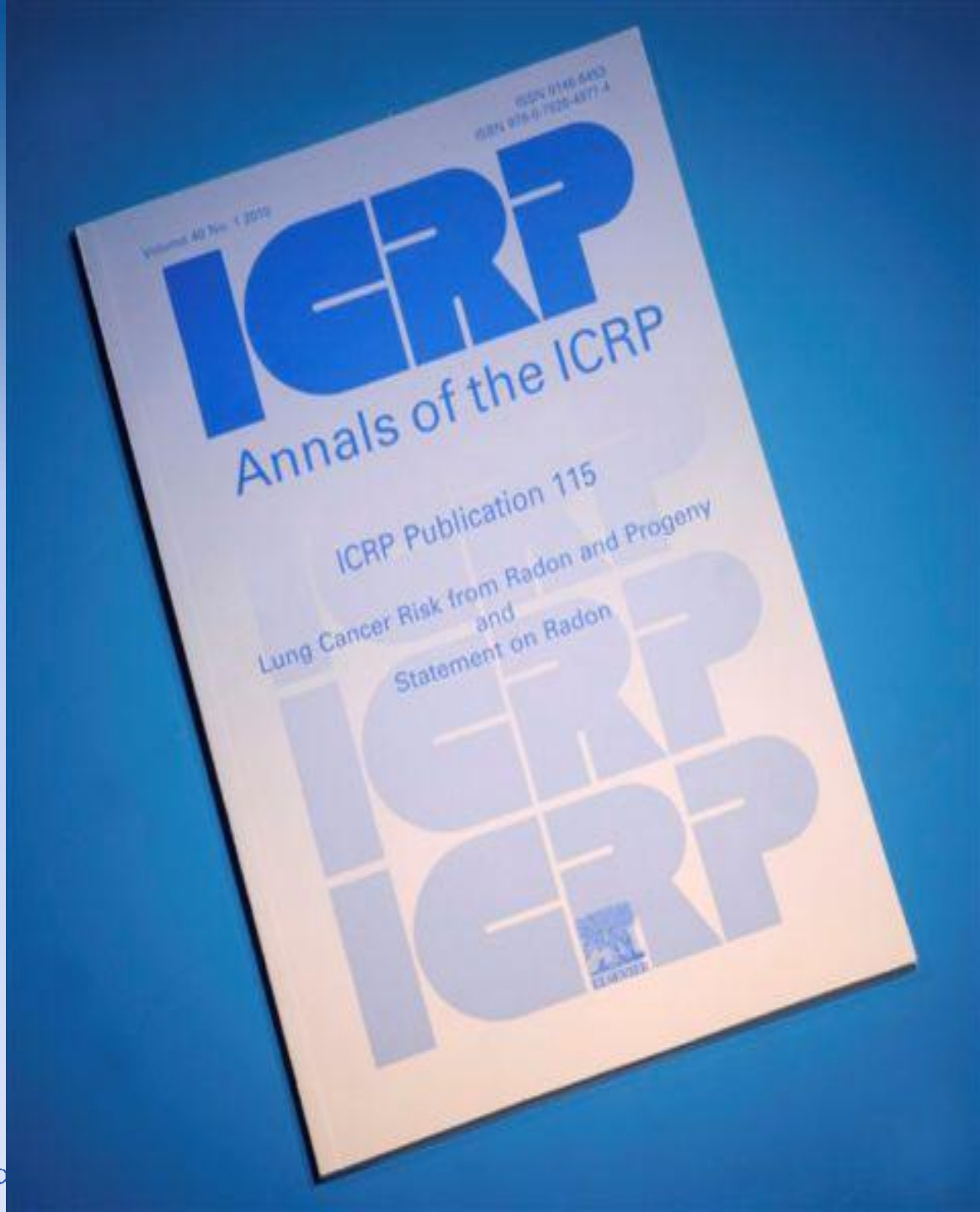
By Michael_Yong | Posted: November 19, 2014 By Twitter: @michael_yong



Publication 115

Lung cancer risk from radon and progeny and Statement on Radon.

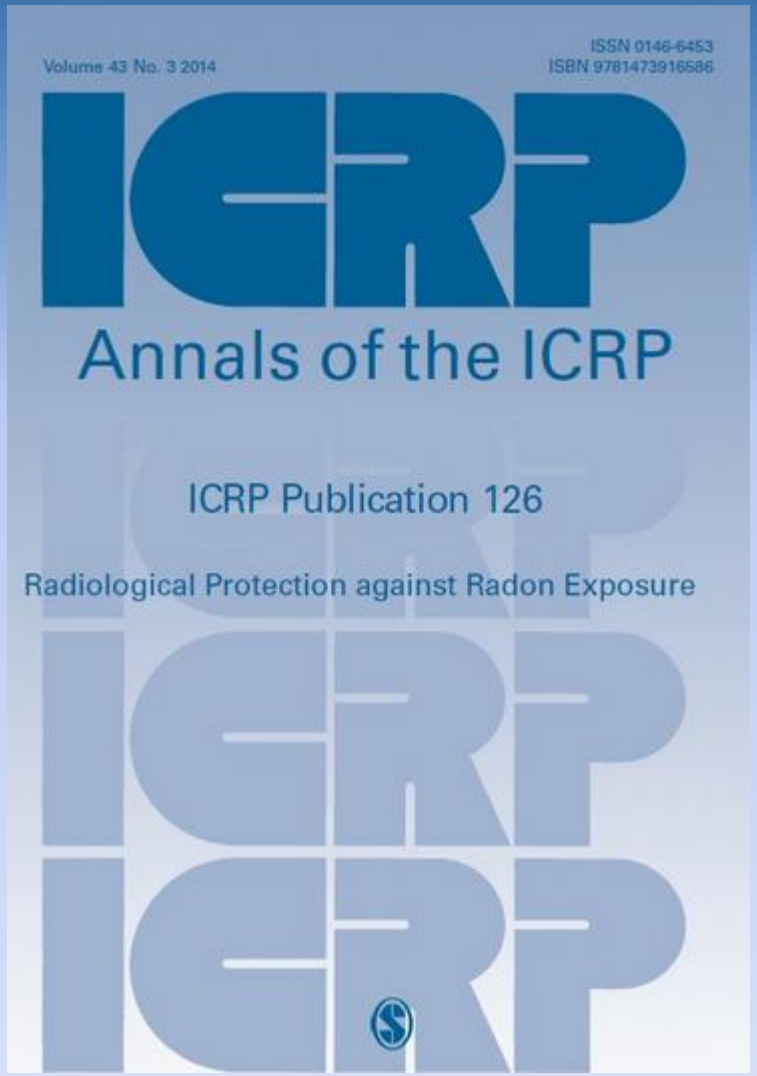
(2010)



Publication 126

Radiological Protection against Radon Exposure.

(2014)



Epidemiological approach

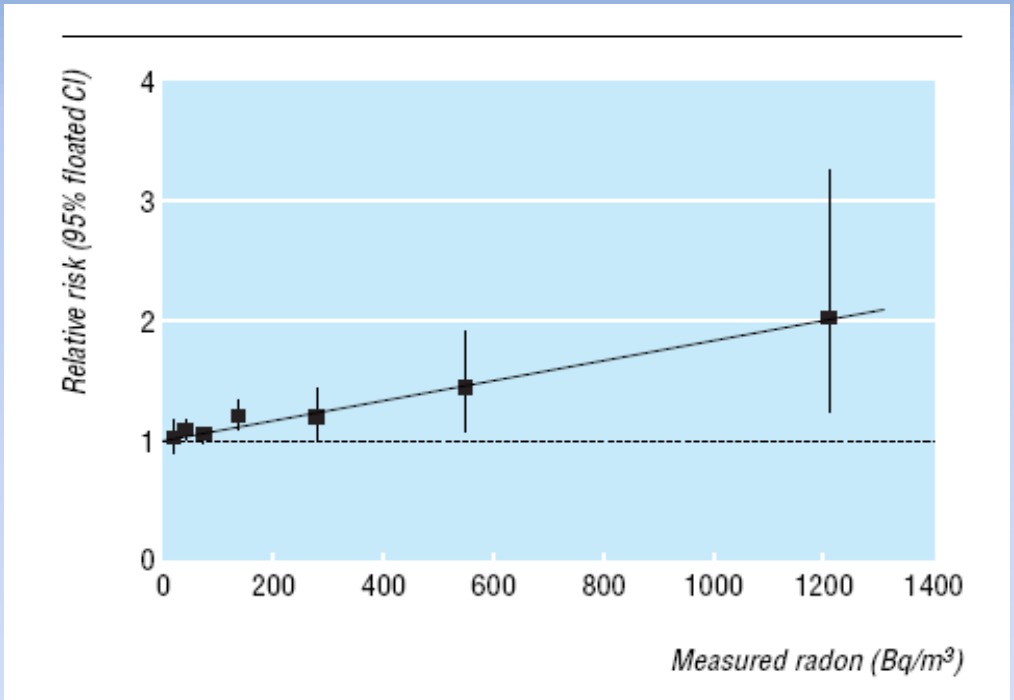
Domestic ^{222}Rn exposures

Three joint analyses : European, North American, Chinese

- Risk of lung cancer increases with increasing cumulative exposure to radon decay products;
- Relative risk increases by about 10% per 100 Bq/m^3 increase;
- Risk significant for cumulative exposures < 200 Bq/m^3
- Absolute risk for life-long smokers about 25 times greater than for life-long non smokers.

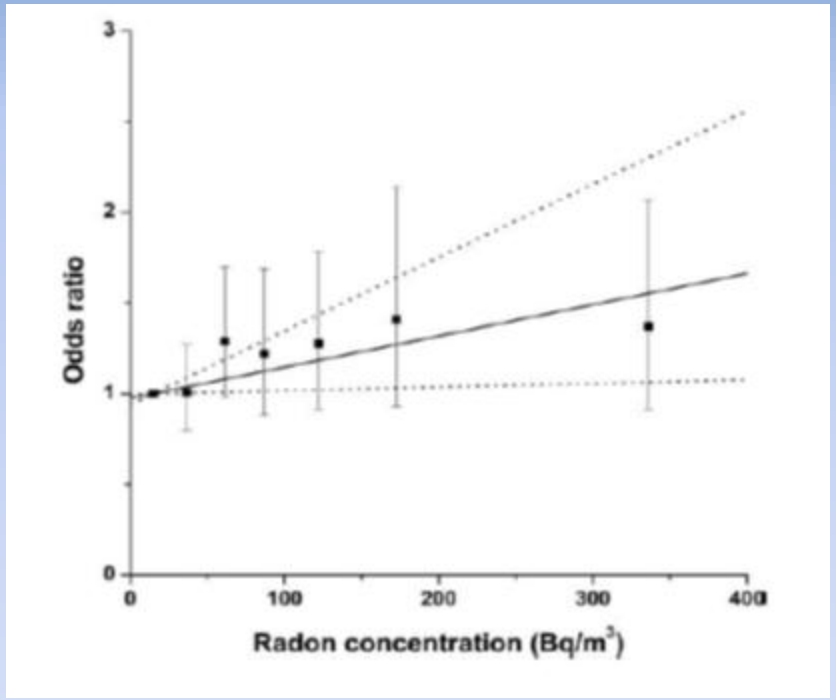
Pooled residential studies

Europe



Darby et al 2005

North America



Krewski et al 2005

Pooled residential studies

Study	Relative risk per 100 Bq/m^3 (CI 95 %)		
	Primary analysis	Restricted analysis	Exposures adjusted for uncertainties
European *(Darby 2006)*	**1.08** (1.03-1.16)	**1.09** (1.03-1.18) (a)	**1.16** (1.05 – 1.31)
North American *(Krewski 2006)*	**1.10** (0.99-1.26)	**1.18** (1.02-1.43) (a)	
Chinese (*Lubin 2004)*	**1.13** (1.01-1.36)	**1.32** (1.07-1.91) (b)	

(a) Only 1 or 2 residences in a 20 year period or more

(b) Only 1 residence in a 30 year period or more

Miner data – Lifetime Excess Absolute Risk (LEAR)

Cohort studies : Canada, Germany, Czech Republic, Sweden, USA, China, Australia

Reference	Model	Background	Risk x 10^{-4} WLM^{-1}
ICRP (1993)	Pub 65	Pub 60	2.83
Tomasek (2008)	Pub 65	Pub 103	2.7
Tomasek (2008)	BEIR VI	Pub 103	5.3
Tomasek (2008)	Czech-French	Pub 103	4.4

Conclusions of Publication 115 and Statement on Radon

Publication 115 proposed a nominal risk coefficient of 5×10^{-4} WLM^{-1} replacing Publication 65 value of 2.83×10^{-4} WLM^{-1}

The Statement on Radon recommended the use of this value for radiation protection purposes and stated that ICRP would in future publish dose coefficients for radon isotopes calculated using biokinetic and dosimetric models.

The statement lowered the upper reference level for homes from 600 Bq/m^3 to 300 Bq/m^3.

The statement recommended 1000 Bq/m^3 as an entry point for applying occupational protection requirements.

Radon dosimetry – epidemiological approach

$$\frac{Risk\ per\ WLM}{Risk\ (detriment)\ per\ Sv} = Sv\ per\ WLM$$

"Dose conversion convention" ICRP 65

Detriment Publication 103

	Detriment x 10^{-2} per Sv			
	Cancer		Hereditary	Total
	Lung	Total		
Workers	1.2	4.1	0.1	4.2
Public	0.9	5.5	0.2	5.7

Detriment Publication 103

	Detriment x 10^{-2} per Sv			
	Cancer		Hereditary	Total
	Lung	Total		
Workers	1.2	4.1	0.1	4.2
Public	0.9	5.5	0.2	5.7

Epidemiological approach

Considering 5×10^{-4} per WLM lung cancer risk and the following total detriments (publication 103):

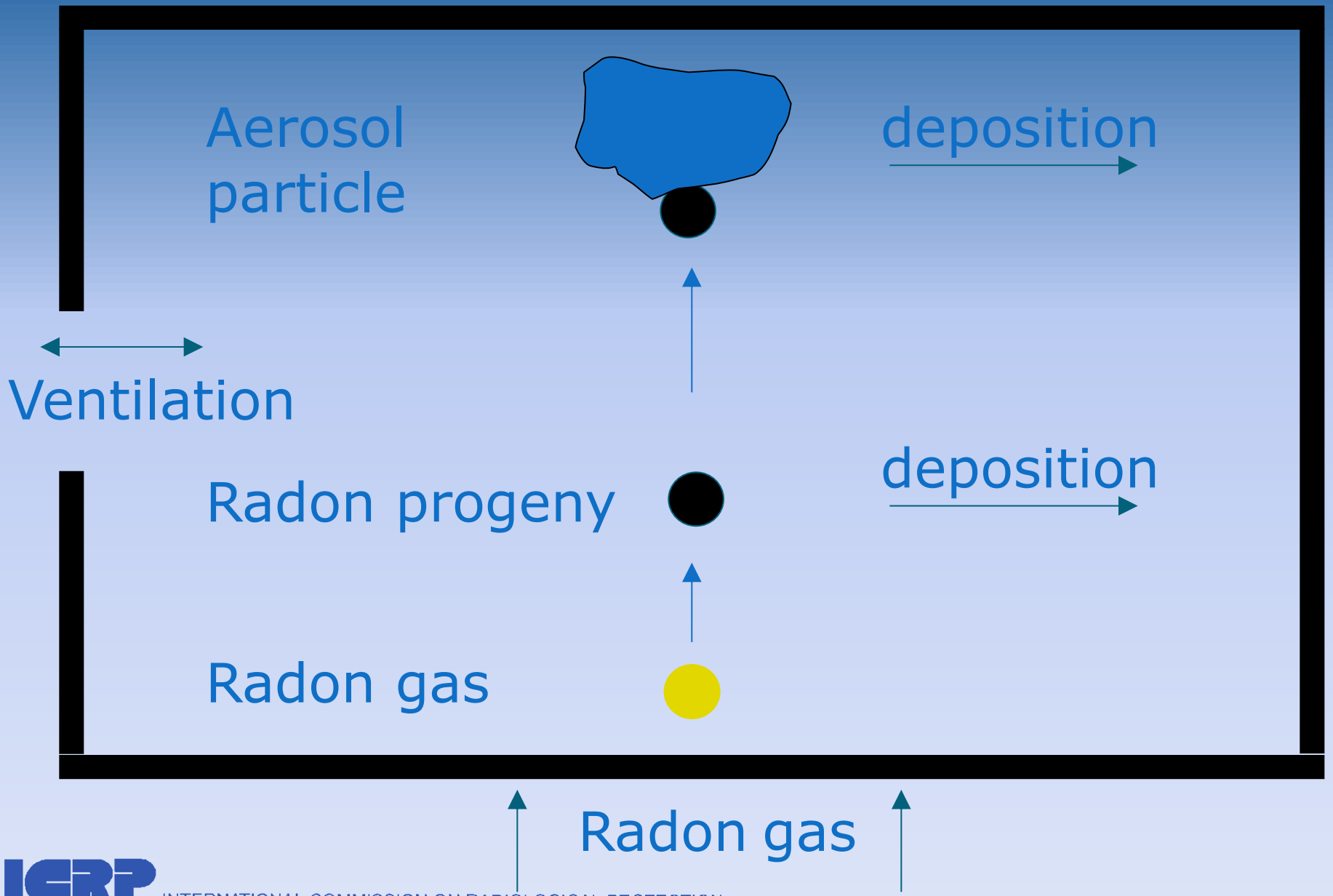
Workers	4.2×10^{-2} Sv^{-1}	gives 12 mSv per WLM
Public	5.7×10^{-2} Sv^{-1}	gives 9 mSv per WLM

Dosimetric approach

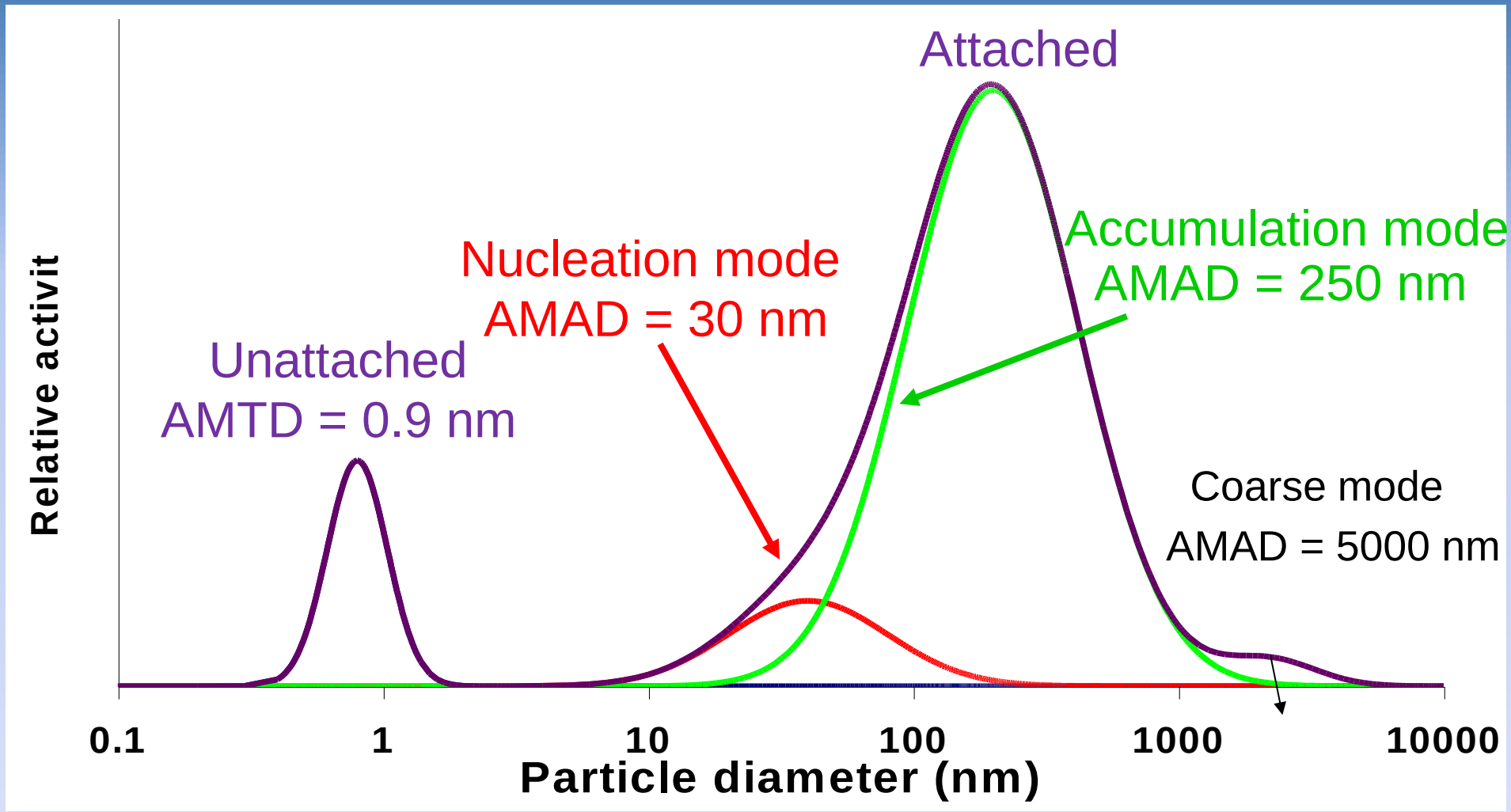
Calculate the equivalent and effective doses using biokinetic models and radiation transport simulation

The ICRP has announced its intention to replace the current dose conversion convention with a dosimetric approach, bringing radon into line with all other internal emitters.

Formation of radon progeny aerosol



Activity size distribution for an indoor workplace



Porstendörfer 2001, Marsh *et al* 2002.

Equilibrium factor, F

F is a measure of the dis-equilbrium between radon gas concentrations and its progeny concentrations.

F = 1

Nuclide	Bq/m^3
^{222}Rn gas	1.0
^{218}Po	1.0
^{214}Pb	1.0
^{214}Bi	1.0

F = 0.3

Nuclide	Bq/m^3
^{222}Rn gas	1.0
^{218}Po	0.6
^{214}Pb	0.3
^{214}Bi	0.2

The value of F depends on the ventilation rate :

Indoors : $F \approx 0.4$ Natural ventilation

Mines : $F \approx 0.2$ Forced ventilation

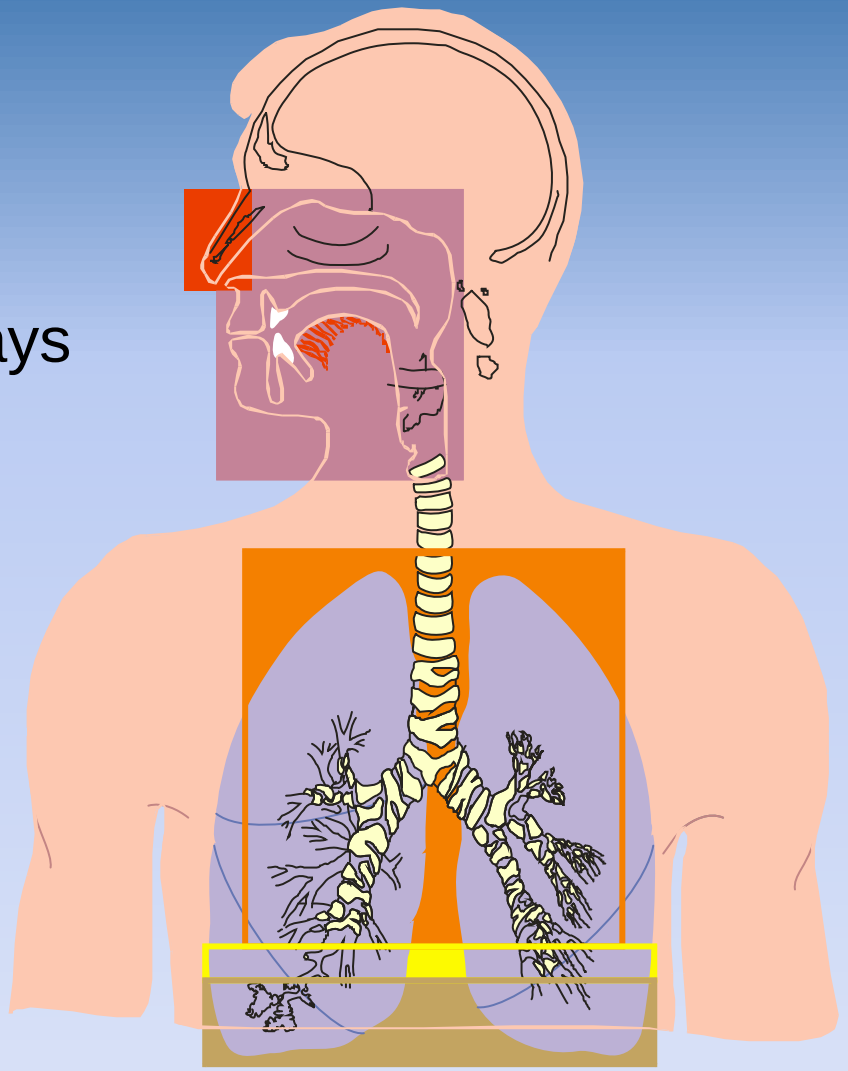
Human Respiratory Tract Model, Pub 66 (1994)

Extrathoracic airways

Bronchial

Bronchiolar

Alveolar interstitial



ET_1

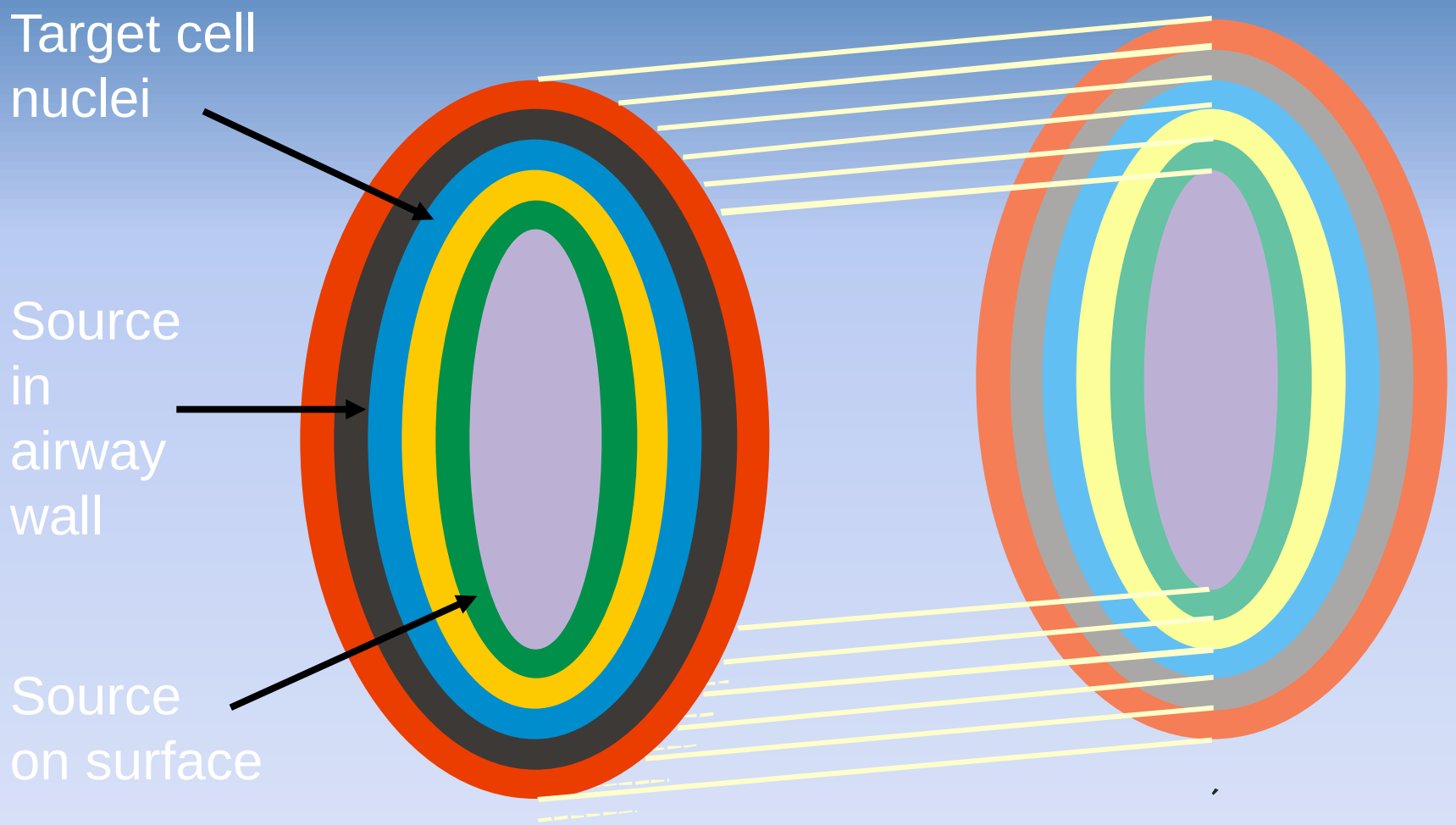
ET_2

BB

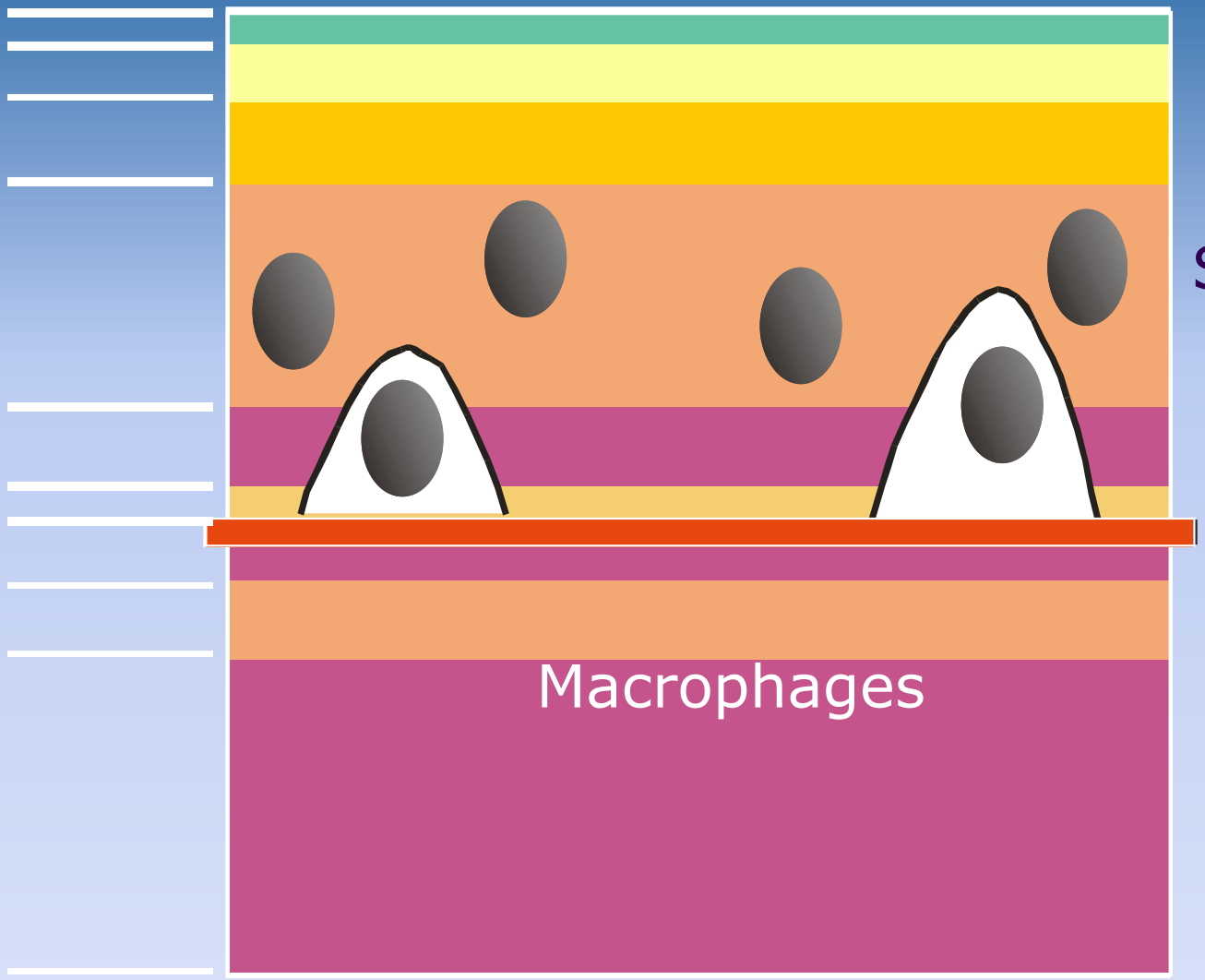
bb

AI

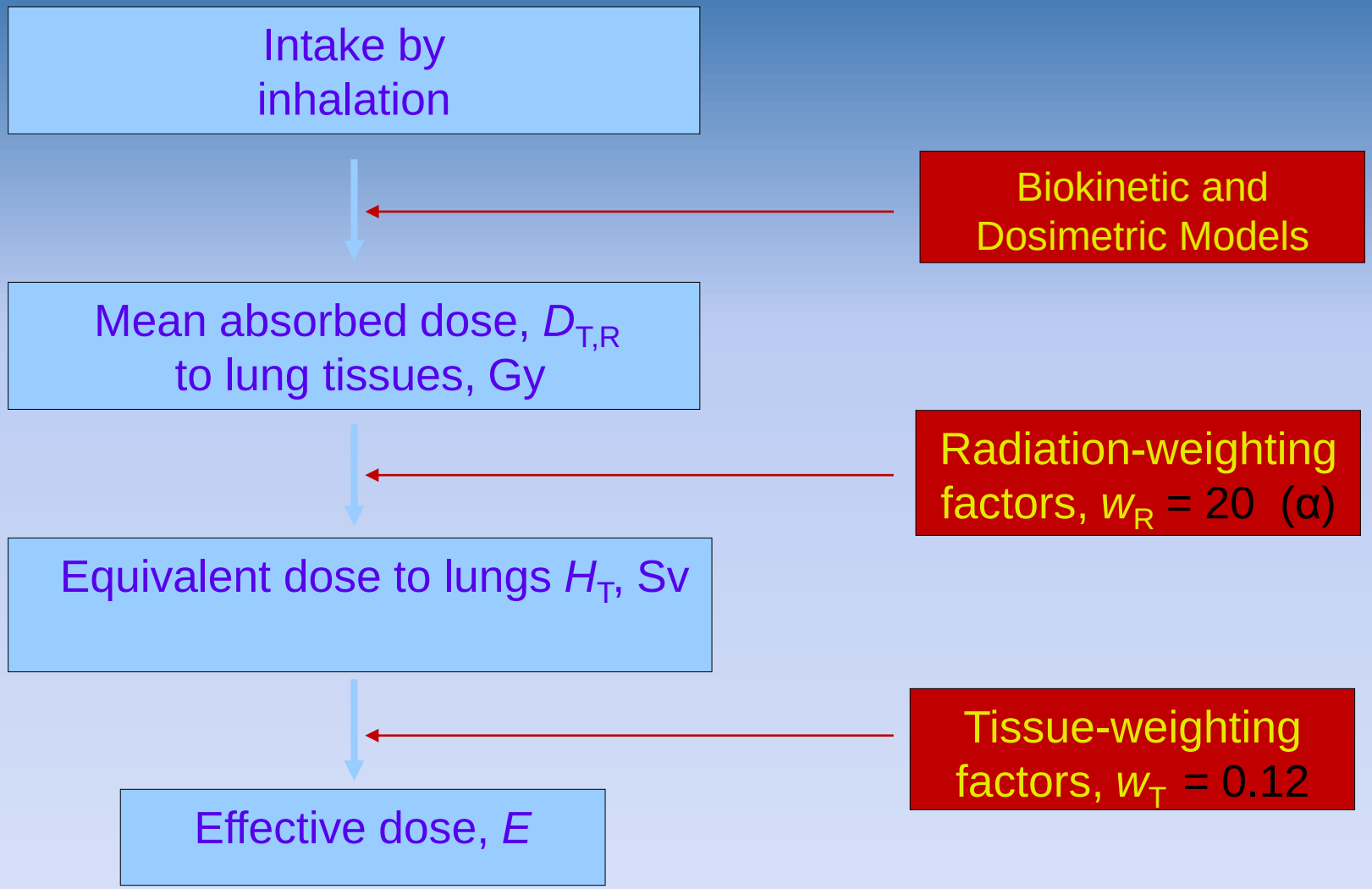
Geometric Model of Airway for Dosimetry



Bronchial (BB) Wall Dosimetry



Calculation for inhaled ^{222}Rn + progeny



Factors affecting dosimetric calculations

- Aerosol characteristics
  - Unattached fraction
  - Size distribution
- Equilibrium factor F (if radon gas is measured)
- Breathing rate

Dosimetric approach preliminary results

		Effective dose mSv per WLM	
Marsh & Birchall 2000	HRTM	15	(home)
James *et al* 2004		21	(home, mine)
Marsh *et al* 2005		13	(home, mine)
Winkler-Heil *et al* 2002		12	(mine)
Deterministic airway generation model		8	(mine)
Stochastic airway generation model		9	(mine)

ICRP dose coefficients – preliminary values

	Equilibrium factor	Unattached fraction, %	Effective dose mSv per WLM
Home	0.4	8	13
Indoor workplace	0.4	8	20
Mine	0.2	1	11

ICRP reference levels

ICRP 115 reference levels

ICRP Statement on Radon (2010)

	Reference Level Bq/m^3	Annual effective dose mSv
Homes	300	17
Workplaces	1000	27
Mines	1000	8

ICRP 115 and Task Group reference levels

ICRP Statement on Radon (2010)

	Reference Level Bq/m^3	Annual effective dose mSv
Homes	300	17
Workplaces	1000	27
Mines	1000	8

ICRP Committee 4 Task Group on Radon

Buildings - work	300	8

ICRP 115 and Task Group reference levels

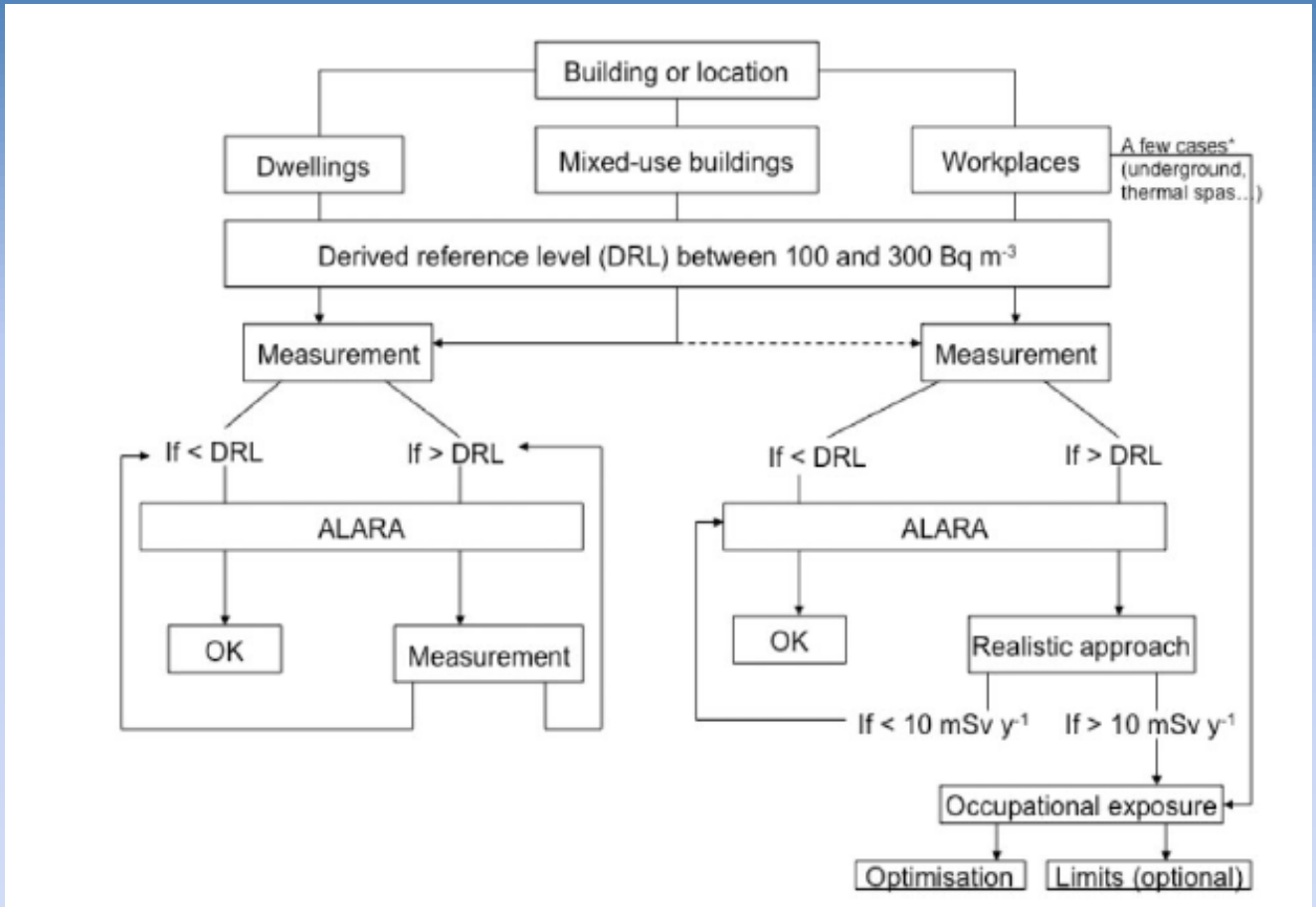
ICRP Statement on Radon

	Reference Level Bq/m^3	Annual effective dose mSv	
Homes	300	17	(12)
Workplaces	1000	27	
Mines	1000	8	

ICRP Committee 4 Task Group on Radon

Buildings - work	300	8	(5)

ICRP 126



ICRP 126 General approach for the management of radon exposure

Conclusions

- There is strong evidence that exposures to radon and its progeny may result in lung cancer. Radon exposure is the second leading cause of lung cancer after smoking.

- Risk of lung cancer for homes and other buildings may be controlled on the basis of radon concentrations in Bq/m^3 .

- ICRP will publish reference dose coefficients for inhalation and ingestion of radon isotopes and progeny.

- The reference level of 300 Bq/m^3 is equivalent to:

  17 mSv (12 mSv) for Homes

  8 mSv (5 mSv) for Workplaces

Thank you for your attention

John Hunt

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Units (concentration)

Working level

- Defined in terms of potential alpha energy concentration (PAEC).

1 Working Level (WL) is any combination of short lived decay products in 1 litre of air which will ultimately emit 1.3×10^5 MeV of alpha energy.

- **Radon gas concentration**
  - Measured in Bq m^{-3}

Units (exposure)

Working Level Month (WLM)

1 WLM is an exposure to 1 WL for 1 month (170 h).

Annual average exposure of radon gas in a home of 230 Bq m^{-3} = 1 WLM

- **Radon gas exposure**
  - Bq m^{-3} h

1 Bq m^{-3} h = F x 1.57 x 10^{-6} WLM

Where F is the equilibrium factor