Radon in Homes and Lung Cancer Risk

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Plan of talk

1. Introduction to radon and lung cancer
2. Estimating the risk in homes
3. Reducing radon-related deaths

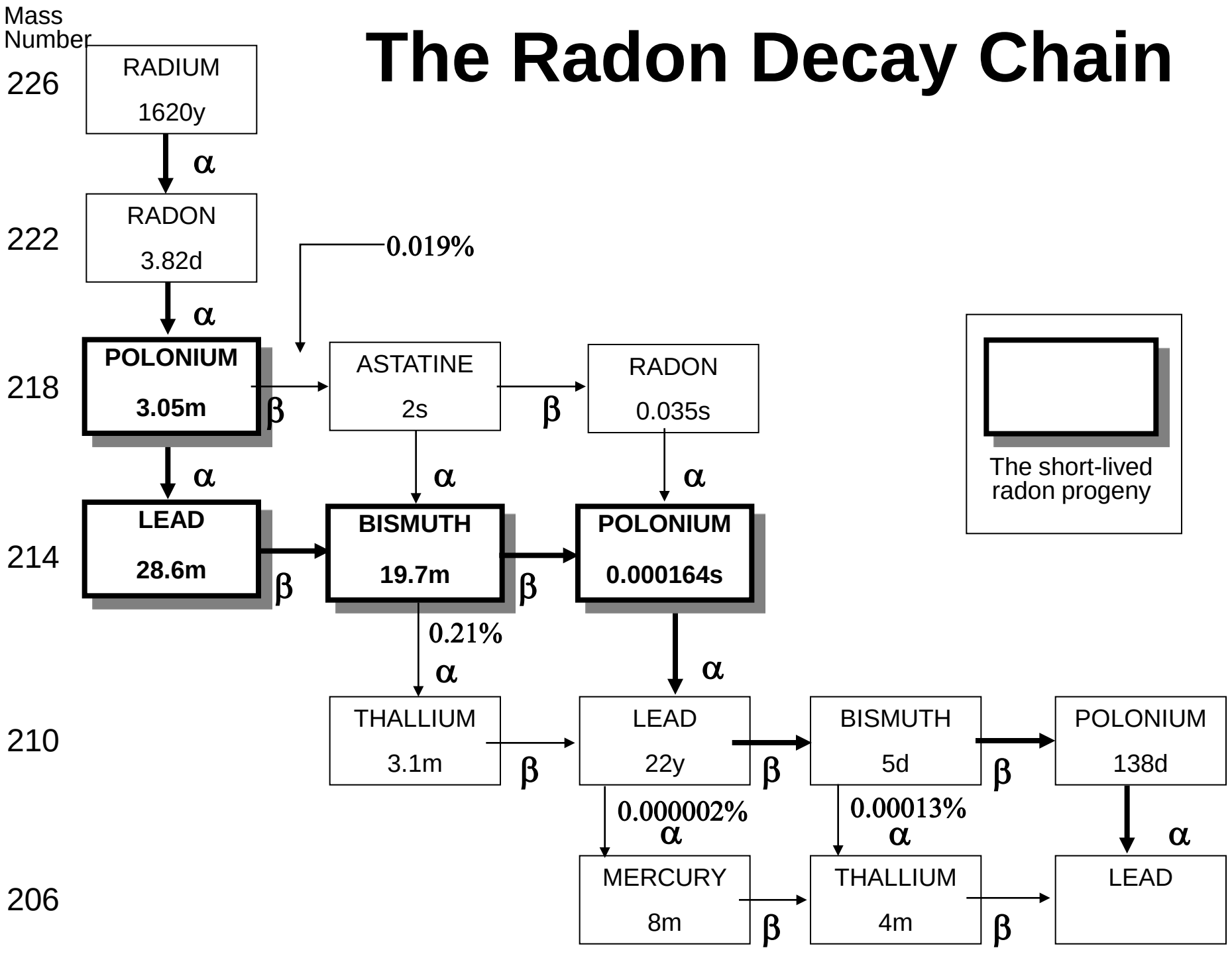
Orion Nebula

Hubble Space Telescope view of five young stars

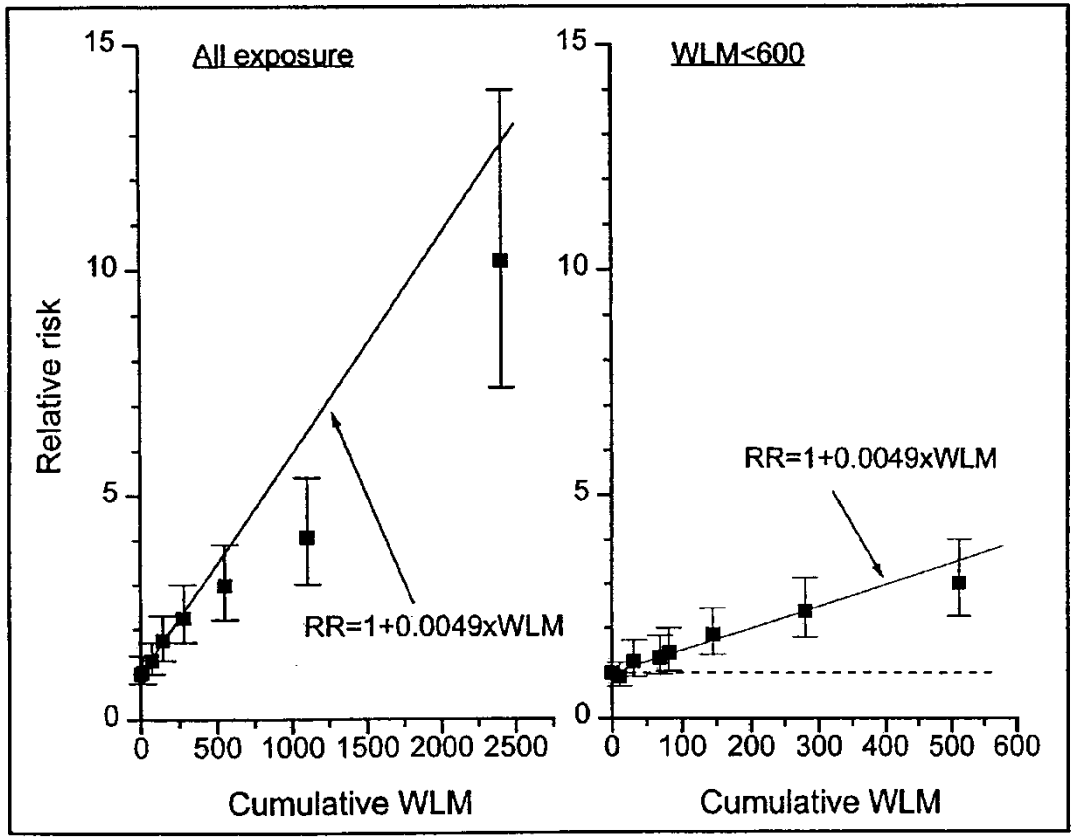
Primordial radionuclides on planet earth include ^{238}U with half-life ~10^9 years

5th decay product of ^{238}U is ^{226}Ra

The Radon Decay Chain

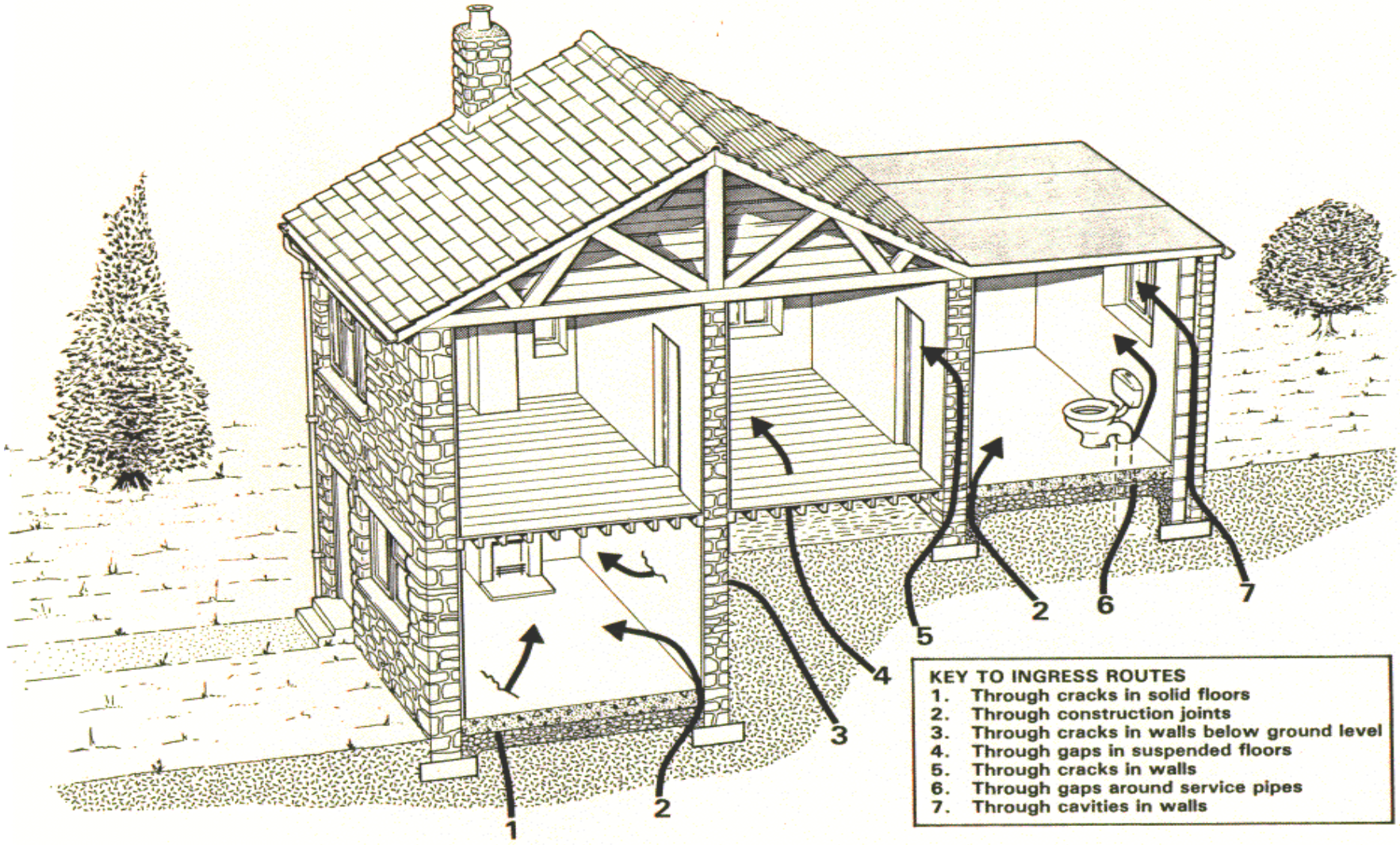


Relative risk of death from lung cancer in uranium and other radon-exposed miners (from Lubin et al, 1995)



WLM: measure of exposure to radon that takes into account total potential alpha-particle energy from all the short-lived radon progeny and length of time exposed

Routes by Which Radon Enters a Dwelling



Measuring radon concentrations in buildings

PADC (poly allyl diglycol carbonate) is enclosed in a domed holder which allows radon gas to enter but excludes dirt, moisture and radon decay products. The number of tracks is proportional to the radon gas exposure.

Average concentration of radon gas in UK homes: 21 Bq/m^3

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Radon in Homes and Lung Cancer Risk: Collaborative Analysis of Individual Data from 13 European Case-Control Studies

S Darby, D Hill, A Auvinen, JM Barros-Dios, H Baysson, F Bochicchio, H Deo, R Falk, F Forastiere, S Farchi, A Figueiras, M Hakama, I Heid, N Hunter, L Kreienbrock, M Kreuzer, F Lagarde, I Mäkeläinen, C Muirhead, W Oberaigner, G Pershagen, A Ruano-Ravina, E Ruosteenoja, A Schaffrath Rosario, M Tirmarche, L Tomášek, E Whitley, HE Wichmann, R Doll

Br Med J 2005;330:223-7 on www.bmj.com

& Scandinavian Journal of Work Environment and Health 2006, Supplement 1

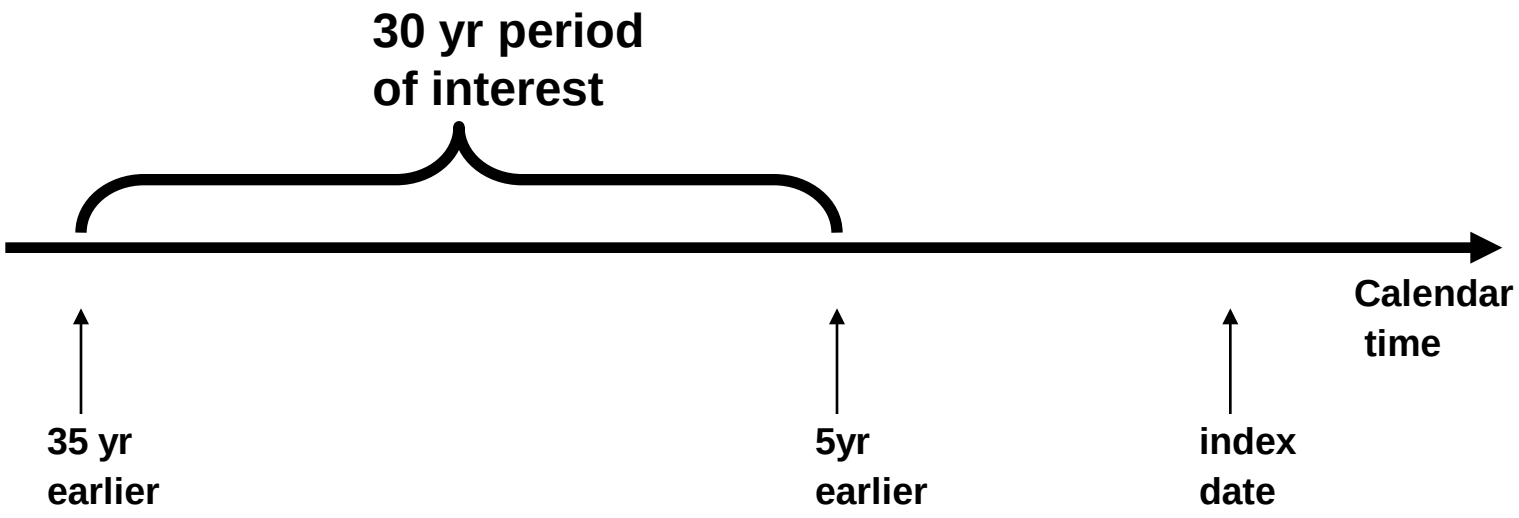
Dedicated to Olav Axelson (1937-2004)

Designing studies of residential radon:

Need:

- **Statistical power: eg large case-control design**
- **Individual radon exposure histories**
- **Individual smoking histories**
- **Information on year-to-year random variability in residential radon measurements**

Period of interest for radon concentrations



Time-weighted average measured radon concentration for each subject
Average no of years measured: 23/30

Estimates for years with no measurements

European case-control studies of residential radon and lung cancer

Study	Number of subjects with lung cancer	Number of control subjects
Austria	183	188
Czech Republic	171	713
Finland: nationwide	881	1435
Finland: south	160	328
France	571	1209
Germany: Eastern	945	1516
German: Western	1323	2146
Italy	384	405
Spain	156	235
Sweden: nationwide	960	2045
Sweden: never-smokers	258	487
Sweden: Stockholm	196	375
United Kingdom	960	3126
Total number of subjects	7148	14,208
	Mostly smokers	Mostly non-smokers

% of controls who were lifelong non-smokers

Measured radon (Bq/m^3)	% who were lifelong non-smokers
<100	39
100-199	40
200-399	41
400-799	46
800+	48
p for trend	*0.001*

Percentages calculated after stratification for study, age, sex, and region of residence

Effect of stratification for smoking

Stratification	% increase in lung cancer risk per 100 Bq/m^3	95% CI	p
A. Standard only*	2.3	(-0.5, 6.1)	0.64
B. Standard plus smoking in 7 groups†	5.2	(1.1, 10.7)	0.009
C. Standard plus smoking in 20 groups‡	8.4	(3.0, 15.8)	0.0007

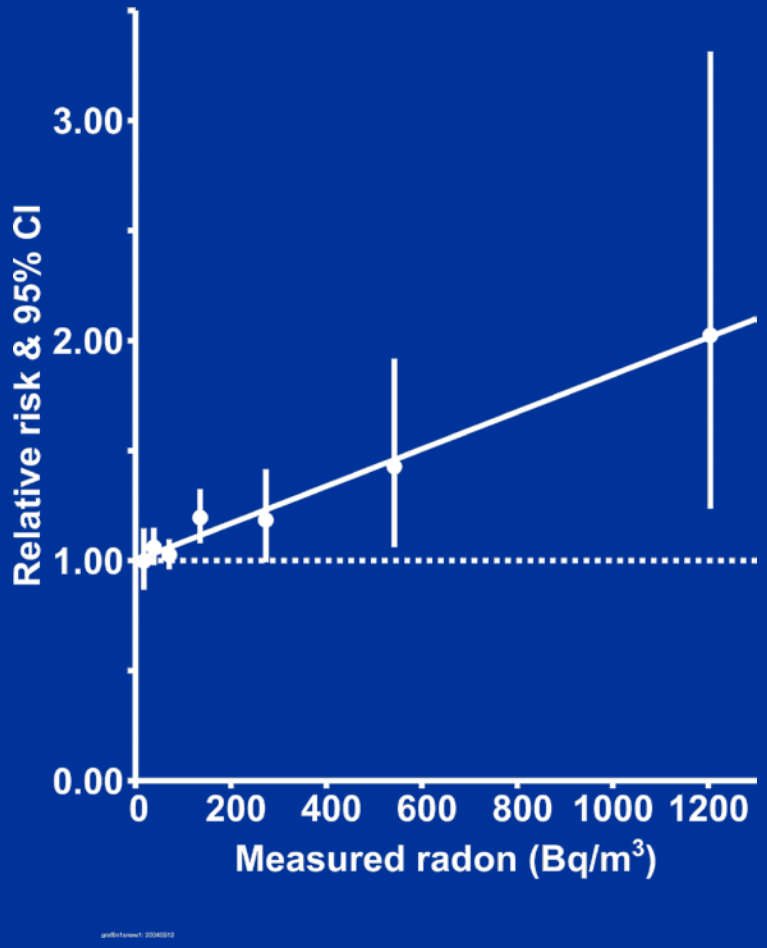
*ie Study, region, age, sex

†Never/current cig(<15, 15-, 25+ per day), ex(<10y, 10+y), other

‡Including age at start (<15, 15-, 18-, 21+y) for current smokers and cigs/day (<15, 15-, 25+) for ex-smokers

Relative risk of lung cancer *versus* measured radon

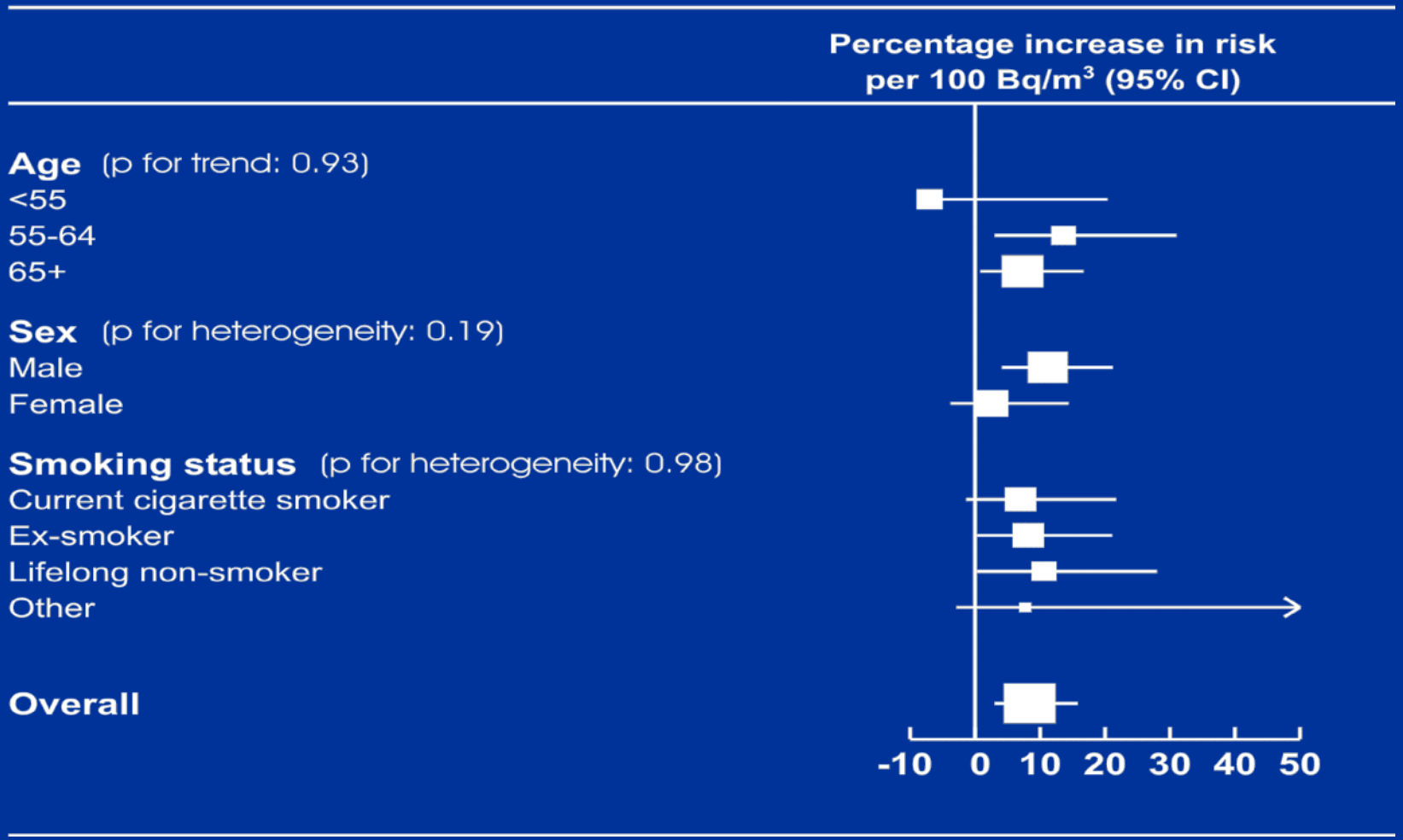
(with stratification for study, region, age, sex, and 20 groups of smokers)



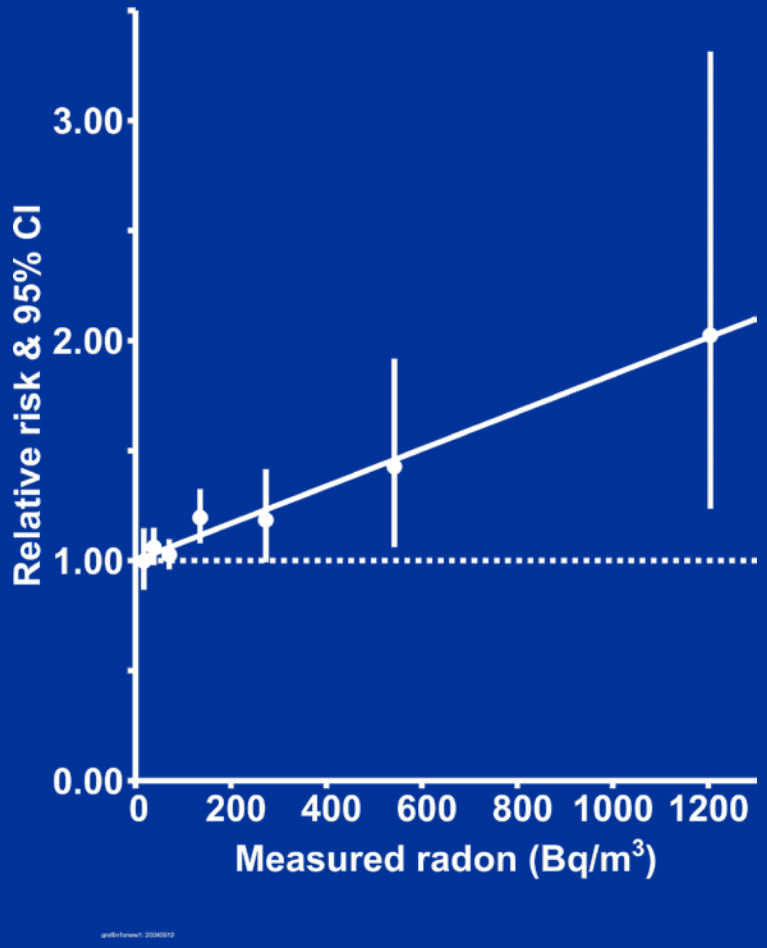
Effect at low concentrations

Measured radon	Lung cancers	Percentage increase in lung cancer risk per 100 Bq/m^3	95% CI	p value
All values	7,148	8.4	(3.0, 15.8)	0.0007
<200 ($Bq/m^{3)}$ only	6,479	14.0	(0.4, 30.9)	0.04

Variation in risk estimate by age, sex, smoking



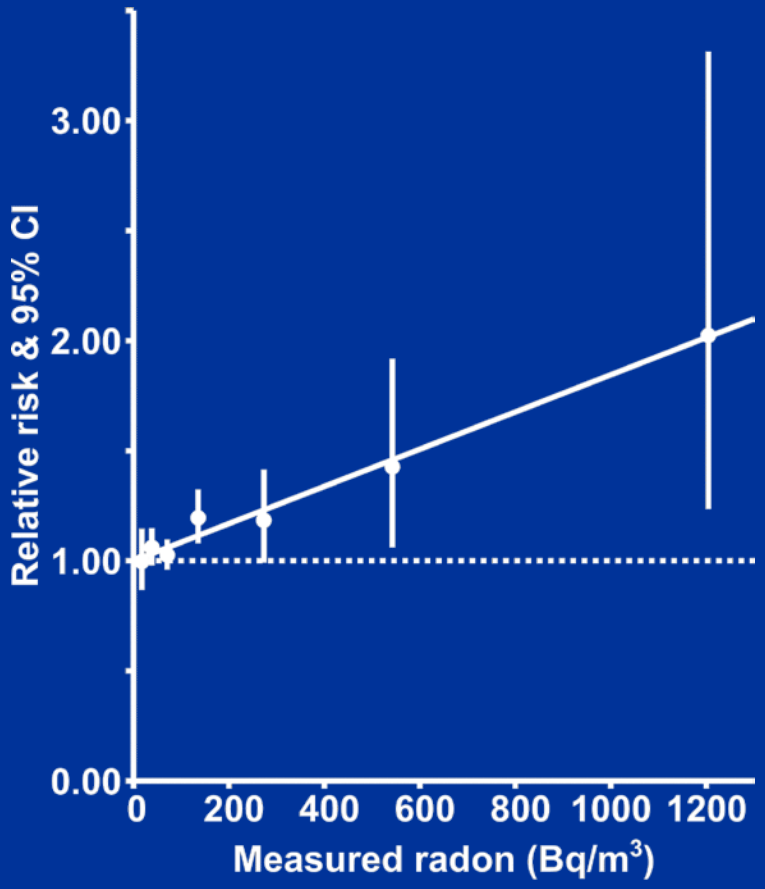
Relative risk of lung cancer *versus* measured radon

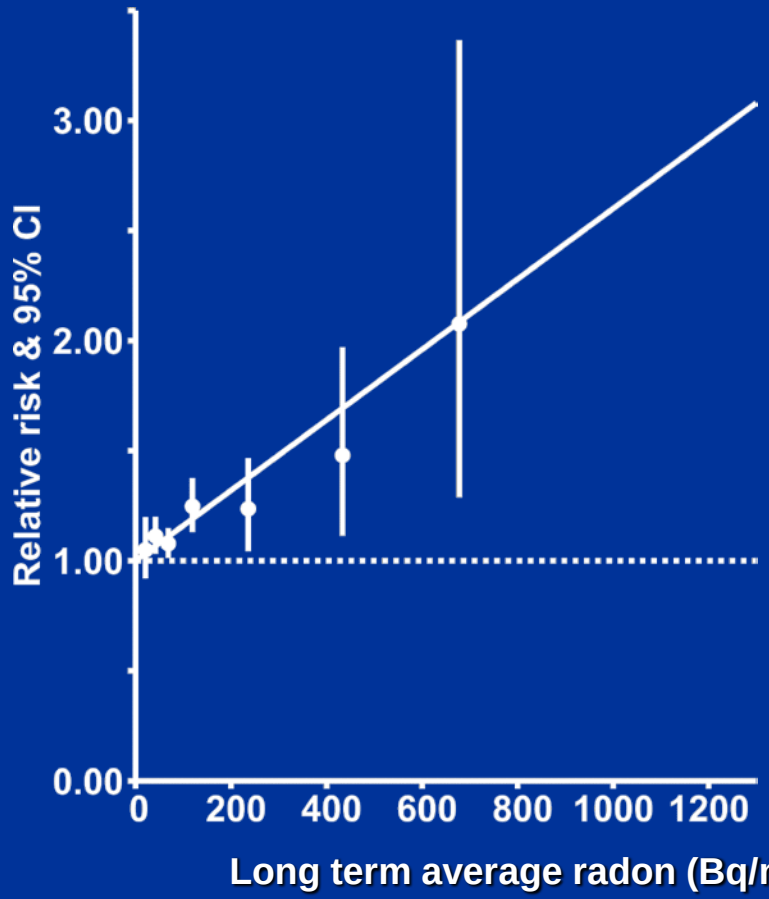


Year-to-year variability of radon gas measurements in the same dwelling

Location	No of dwellings	Coefficient of year-to-year variation on linear scale
Czech Republic	960	36%
Finland	301	62%
Italy	80	17%
Sweden	44	39%
United Kingdom	218 & 69	51% & 44%

Relative risk of lung cancer according to measured and long term average radon concentration





Final Risk Estimate

After detailed stratification for smoking history,

and also allowing for year-to-year variation in measured radon concentration,

lung cancer risk increased by:

16% per 100 Bq/m^3 95% CI (5, 31)

Estimates of the risk of lung cancer from radon in different data sets

Data	No of lung cancers	% increase per 100 Bq/m^3	
		Measured radon	Allowing for year-to-year variation
European indoor	7148 (13 studies)	8% (95% CI 3,16)	16% (95% CI 5,31)
North American indoor	3662 (7 studies)	11% (95% CI 0,28)	?
Chinese indoor	1050 (2 studies)	13% (95% CI 0,36)	?
Miners <0.5WL	All: 2787 <50 WLM: 468 (11studies)	All: 19% <50 WLM: 30%	?

Conclusions re: estimating the risk in homes

- **Strong direct evidence that radon causes lung cancer in the general population**
- **600 Bq/m^3 doubles the lung cancer risk**
  200 Bq/m^3 adds 1/3 to lung cancer risk
  -*regardless of age, sex, smoking status*
- **Significant dose-response relationship even below 200 Bq/m^3**

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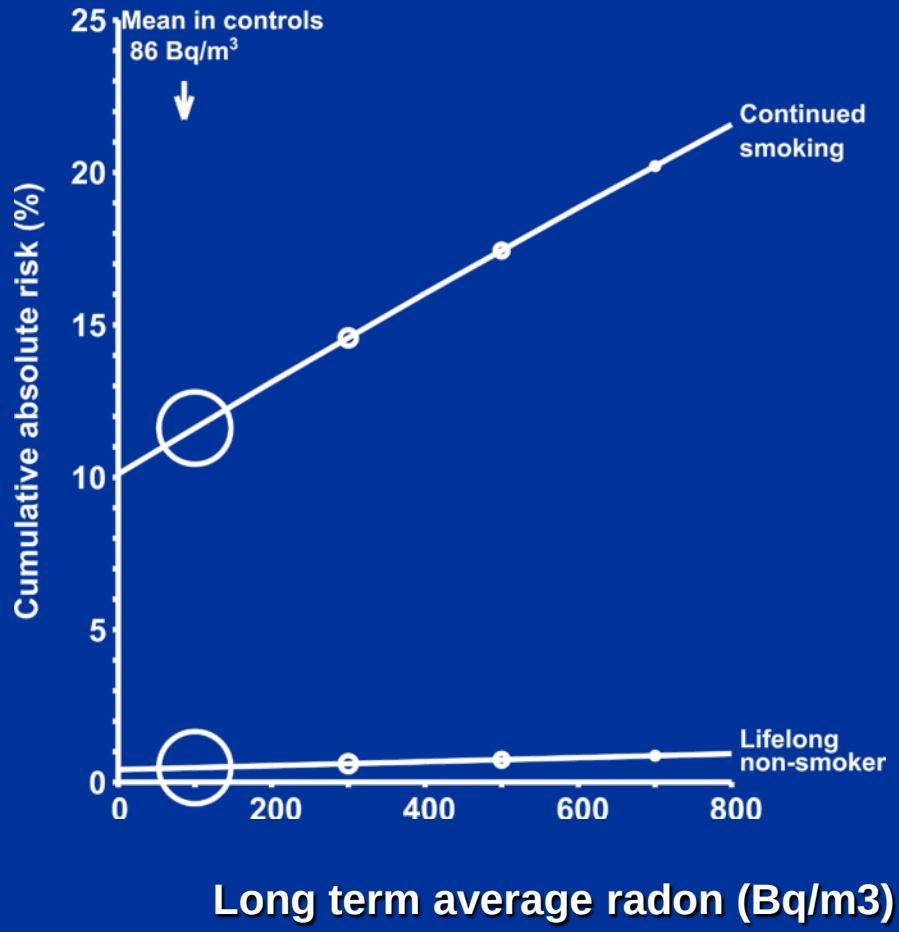
Risks from smoking (from European pooling study)

Smoking status	Relative risk*	
	Males	Females
Lifelong non-smoker	1.0**	1.0
Current cigarette (<15 per day)	13	5.8
Current cigarette (15-24 per day)	26	11
Current cigarette (25+ per day)	40	17
Ex-smoker (<10 years)	21	5.5
Ex-smoker (10+ years)	5.0	1.3
Other	8.3	1.5

*Risks estimated after stratification by study, age, sex and region of residence **Baseline category

Cumulative absolute risk of lung cancer death by age 75

(from European pooling study plus ACS lung cancer rates in never smokers)



Risk of radon-related lung cancer

- **On average risks of getting lung cancer before age 75 at radon levels of 0,100, 400 Bq/m^3 are:**

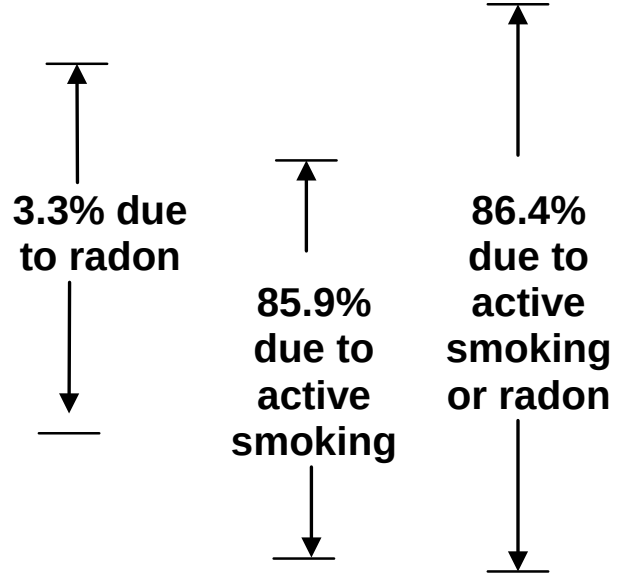
  - Non-smokers: 0.4%, 0.5%, 0.7%

  - Smokers: 10%, 12%, 16%

  (ie 25x more than nonsmokers)

Numbers of lung cancer deaths in the UK each year by cause

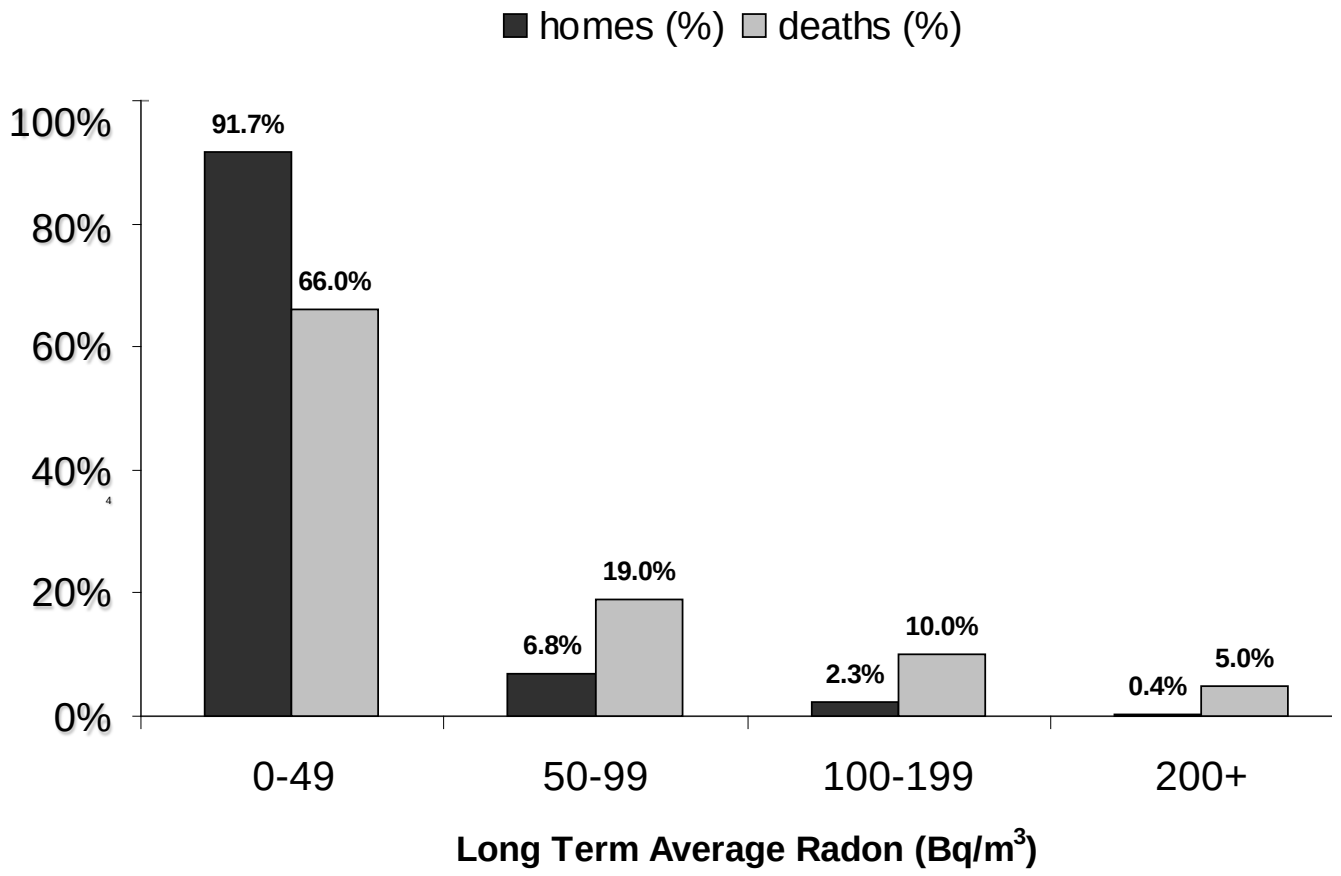
Cause	No of lung cancer deaths
Not caused by active smoking or by residential radon	4664 (13.6%)
Caused by radon but not by active smoking	157 (0.5%)
Caused both by active smoking and by radon:	
- in current smokers	532 (1.6%)
- in ex-smokers	421 (1.2%)
Caused by active smoking and not by radon	28,376 (83.1%)
Total UK lung cancer deaths in 2006	34,150 (100.0%)



Just over 1000 deaths caused by radon each year, ie 1 in 500 of all deaths

Gray et al, BMJ 2009; 338:215-218

Numbers of radon-induced lung cancer deaths each year by long-term average radon concentration at home



Mean radon concentration in all UK homes: 21 Bq/m3

Conclusion re: reducing radon-related deaths

- **Radon in the air of ordinary homes can cause lung cancer, particularly in smokers**
- **Just controlling exposures above an "Action Level" of eg 200 Bq/m^3 avoids only a small fraction of the radon hazard.**
- **Most people killed by radon-induced lung cancer would never have developed the disease if they hadn't also smoked.**

Overall conclusion

- **If the radiation protection community wants to reduce radon-related mortality, then it needs to focus on ordinary people exposed at moderate concentrations, especially smokers, rather than just on people exposed at high concentrations who have the time and inclination to measure the radon concentration in their home**