Epidemiological Studies on Natural Sources of Radiation and Cancer Risk

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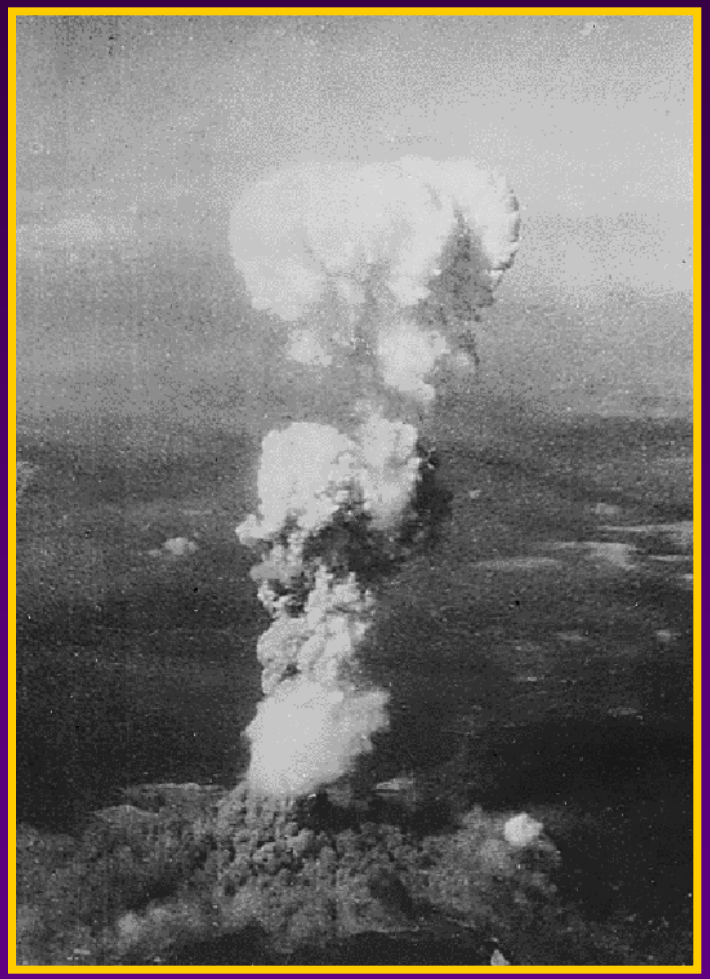
Hiroshima and Nagasaki
6th and 9th August 1945



Naturally Occurring Sources of Radiation

- Cosmic radiation from the Sun and beyond
  - direct external exposure (“cosmic rays”)
  - intakes of radionuclides (^{3}H, ^{14}C) produced in the upper atmosphere
- Terrestrial radiation from long-lived radionuclides and their decay products
  - direct external exposure
  - intakes of radionuclides (^{222}Rn/^{220}Rn in air; ^{238}U, ^{232}Th, ^{226}Ra, ^{210}Po, ^{210}Pb, ^{40}K in food and drink)

Underground Hard-rock Miners

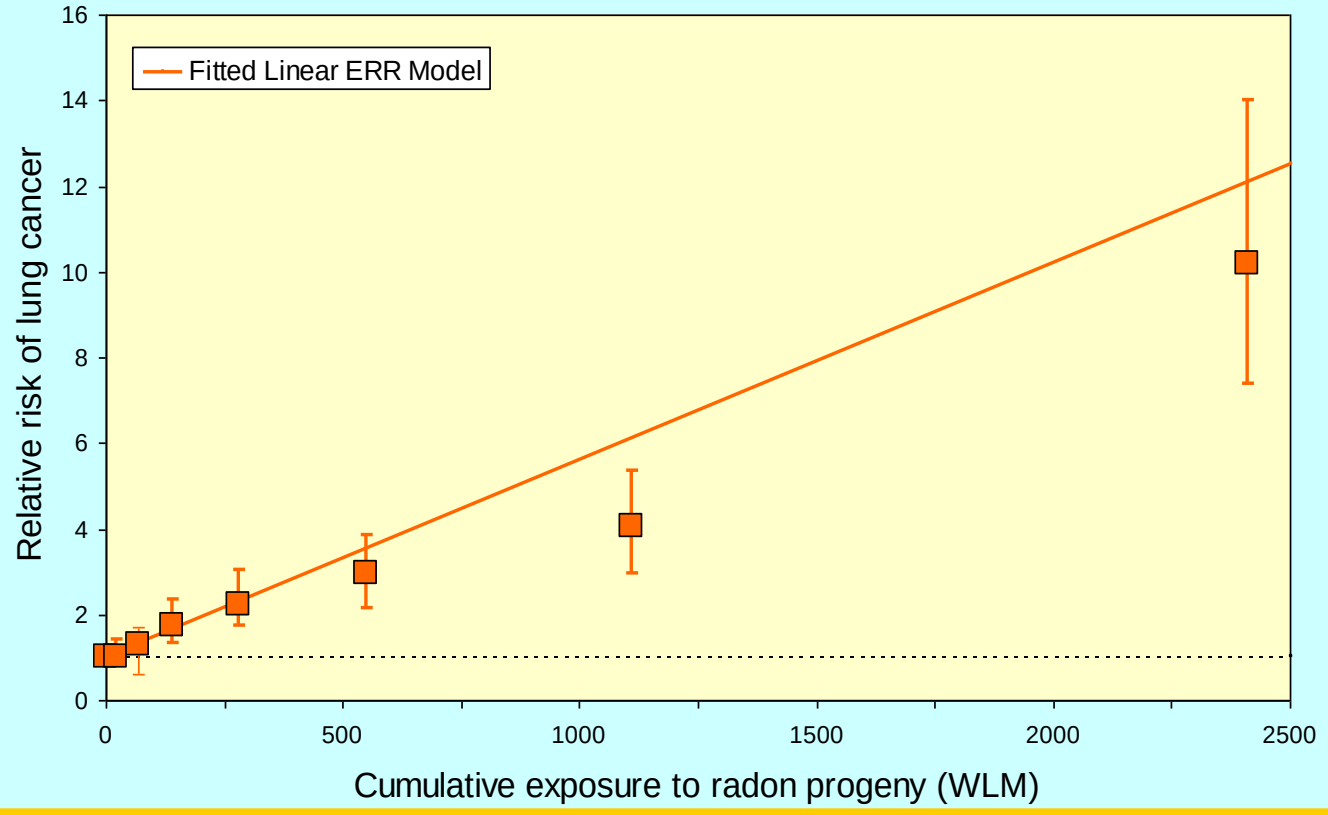
Underground Hard-rock Miners

- Underground hard-rock miners (e.g. uranium, iron, gold, tin miners) inhale radon (mainly ^{222}Rn) and its radioactive decay products.
- In the past, exposures have been high.
- A clear radon-related excess of lung cancer has been demonstrated in many groups of miners, but little evidence for an excess risk of other cancers associated with exposure.

Radon and Lung Cancer

(Lubin *et al.*, *J Natl Cancer Inst* 1995; **87**: 817-27)

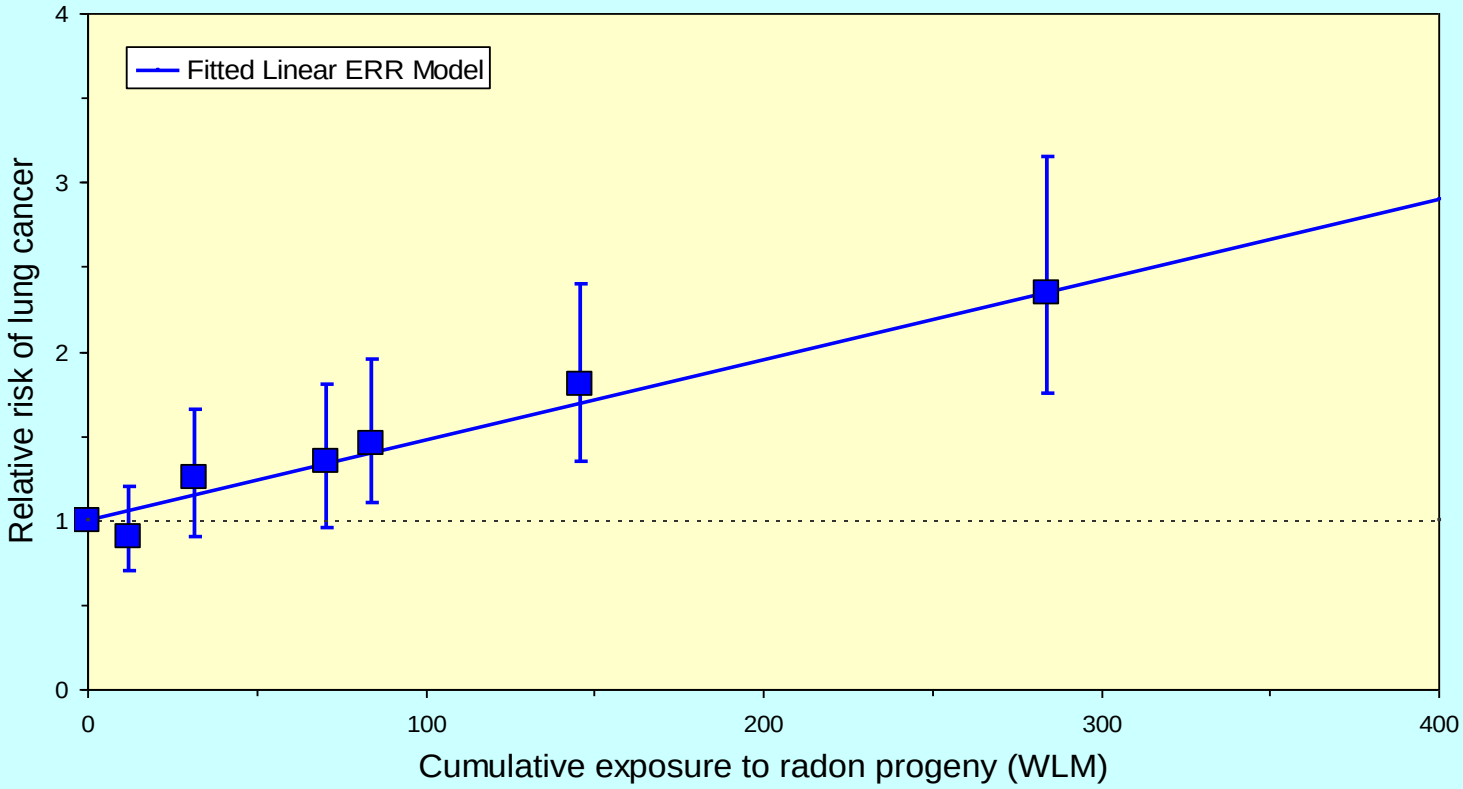
Relative Risk (and 95% CI) of Lung Cancer by Cumulative Exposure to Radon Progeny (Working Level Months, WLM).
Combined Data from Eleven Cohorts of Underground Hard Rock Miners.



Radon and Lung Cancer

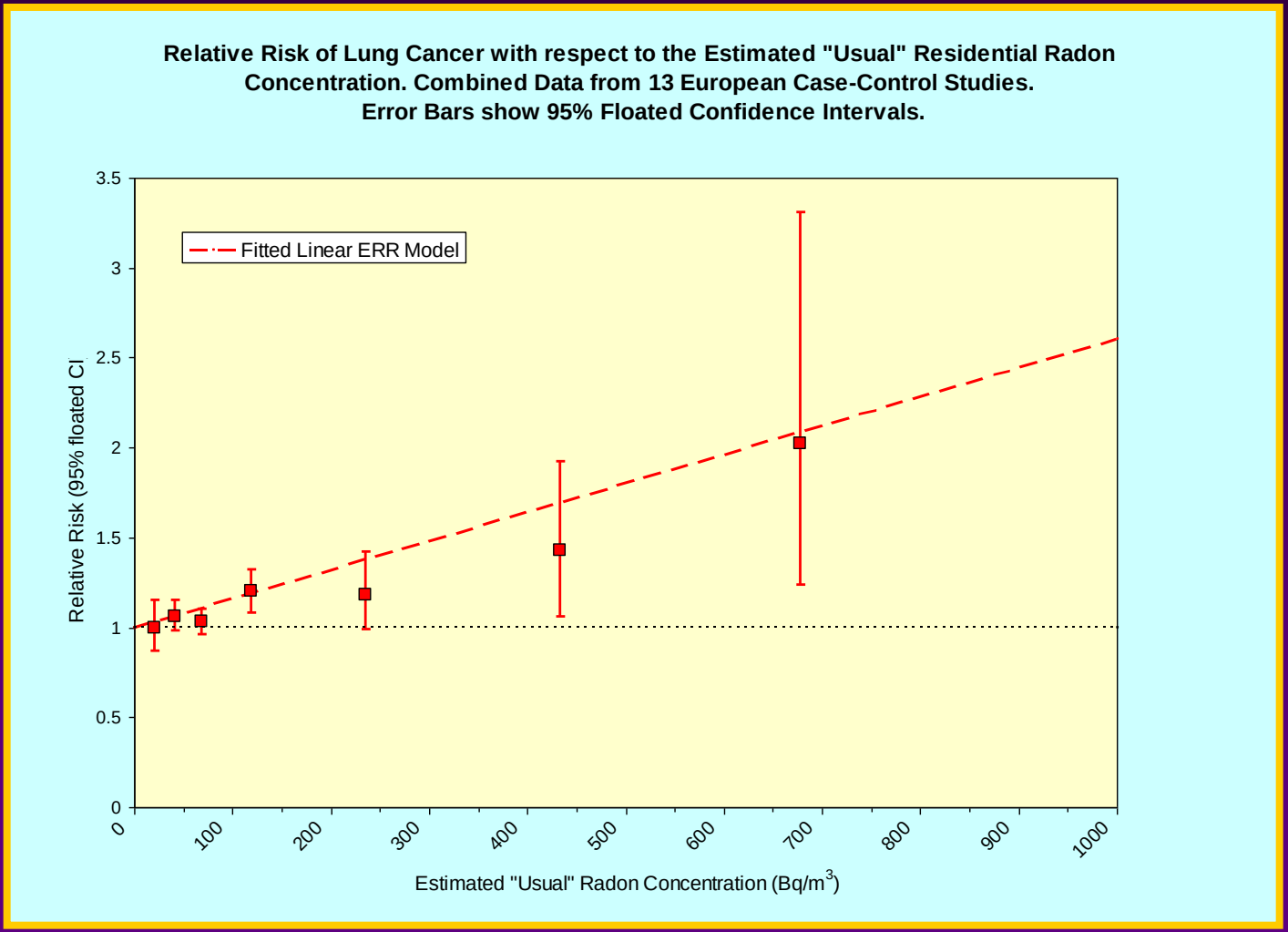
(Lubin *et al.*, *J Natl Cancer Inst* 1995; **87**: 817-27)

Relative Risk (and 95% CI) of Lung Cancer by Cumulative Exposure to Radon Progeny (Working Level Months, WLM). Combined Data for Cumulative Exposure <400 WLM from Eleven Cohorts of Underground Hard Rock Miners.



Residential Radon

(Darby *et al.*, *BMJ* 2005; **330**: 223-8)



Radon and Childhood Leukaemia

- Several studies have examined the potential link between exposure to naturally-occurring inhaled radon and childhood leukaemia.
- The most persuasive of these studies is the nationwide Danish case-control study of Raaschou-Nielsen *et al.* (2008)

(*Epidemiology* 2008; **19**: 536-543)

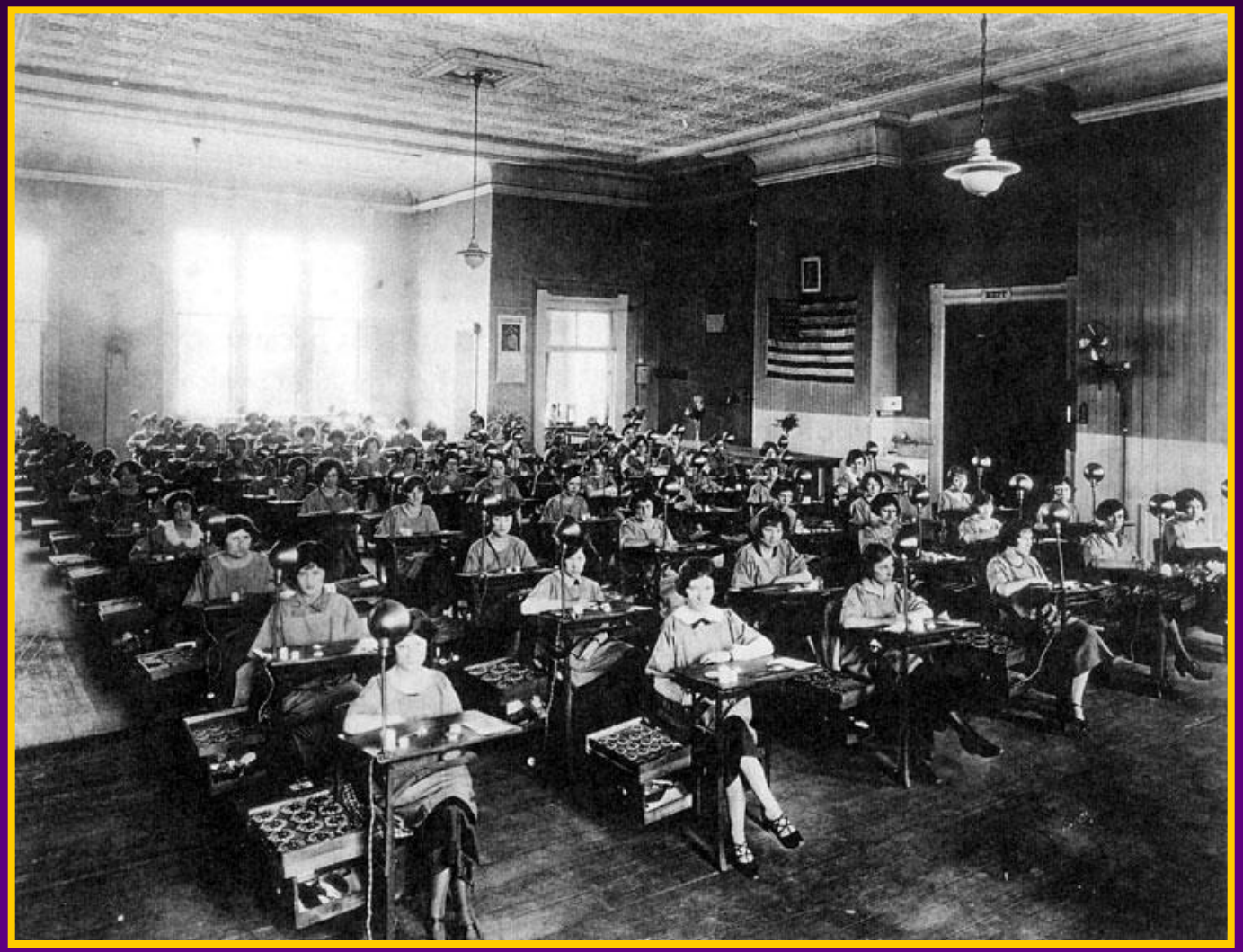
- This study used model-predicted radon concentrations, which avoids participation bias, but introduces exposure uncertainty.

Danish Radon Study

(Raaschou-Nielsen *et al.*, *Epidemiology* 2008; **19**: 536-543)

- Found a statistically significant association between radon exposure and childhood ALL, and inferred that 9% of cases in Denmark could be attributable to radon.
- However, statistical power is *low* (860 ALL cases), and the lower 95% CL for the attributable proportion is 1%, which is compatible with conventional models.
- Accuracy of model-predictions of radon concentrations needs further investigation.

Radium Dial Luminizers



Radium Workers

(Fry, *Radiat Res* 1998; **150**: S21-S29)

- Radium dial painters and radium chemists were exposed to ^{226}Ra (and ^{228}Ra), sometimes heavily (especially in the USA).
- US dial painters experienced a clear excess risk of mortality from bone cancer (pre-1930 workers: O=46, E<1), and also from cancers of the paranasal sinuses and mastoid air cells (from ^{222}Rn produced on the decay of ^{226}Ra in the bone).
- Accurate dosimetry is a problem.

Air Crew

Air Crew

- Air crew are exposed to elevated levels of cosmic radiation (particularly neutrons).
- Several studies of air crew have been conducted, despite the low doses received.
- Study results complicated by the unconventional lifestyles of air crew.
- Studies do not reveal unexpected radiation-related risks.

Medical Exposures

- γ-radiation from ^{226}Ra applicators as radiotherapy (e.g. in the treatment of skin haemangioma).
- Injection with ^{224}Ra as radiotherapy.
- Injection with Thorotrast (^{232}Th based) as a diagnostic contrast medium.

Occupational Exposures

- Uranium processing workers offer an opportunity to study the effects of exposure to uranium. Studies (e.g. in France, USA) have been conducted.
- Other exposures (e.g. thorium) are possible candidates for study.

High Natural Background Radiation Areas (HNBR areas)

- Guarapari, Brazil; Kerala, India; Ramsar, Iran; Yangjiang, China, are all recognised HNBR areas that have been investigated to varying extents.
- Kerala and Yangjiang have been paid particular attention.

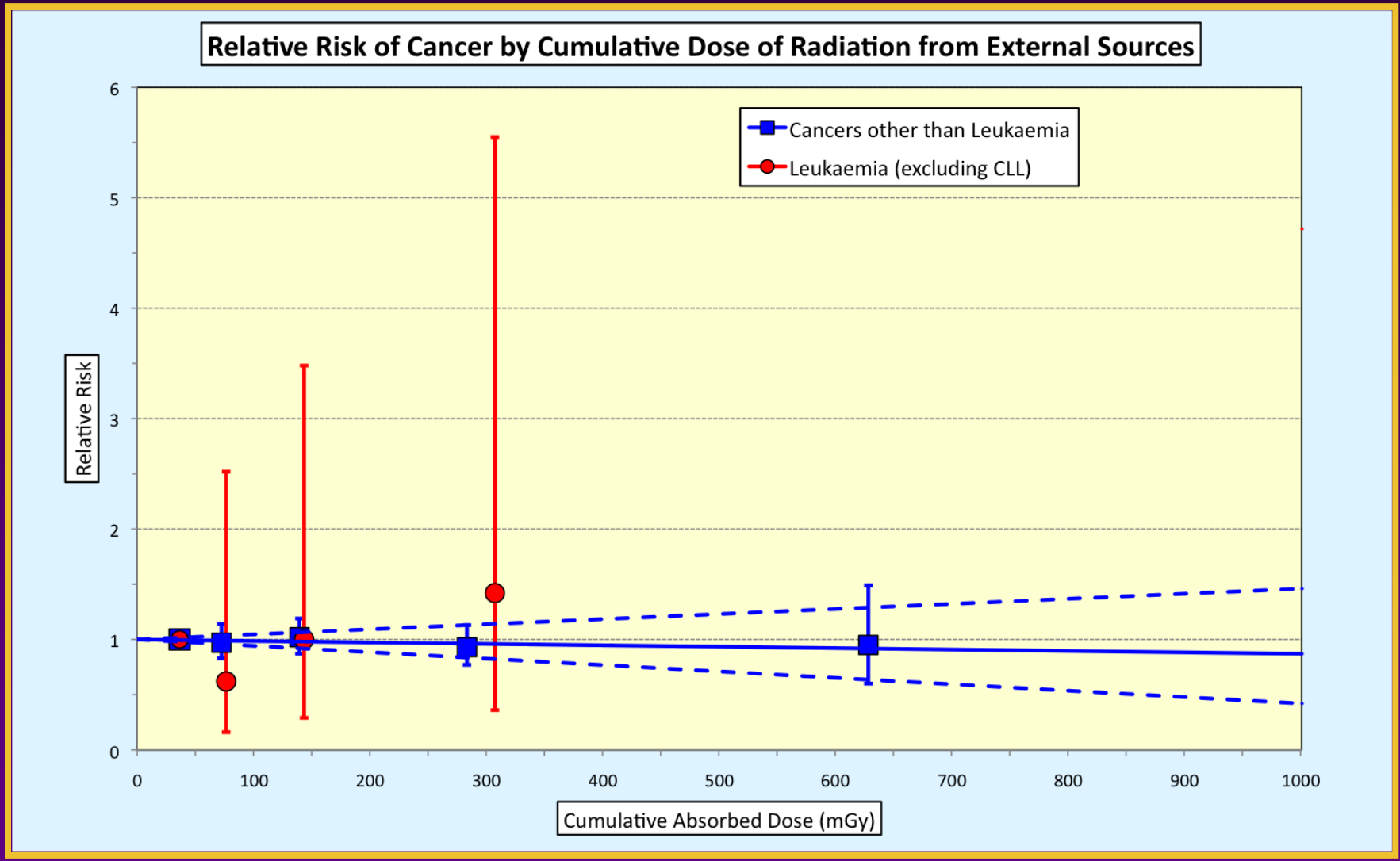
Yangjiang HNBR Area, China

- Tao *et al.* (*Health Phys* 2012; **102**: 173-81) examined mortality in 31 604 residents aged 30-74 years during 1979-1998.
- Cumulative gamma-ray doses by village.
- 6005 deaths (956 cancers) studied.
- No significant correlations, except a *negative* correlation between liver cancer mortality and cumulative dose.

Kerala HNBR Area, India

- Nair *et al.* (*Health Phys* 2009; **96**: 55-66) examined cancer incidence (from a cancer registry) among 69 958 residents aged 30-84 years during 1990-2005.
- >70 000 gamma dose-rates measured.
- 1379 cases of cancer (30 leukaemia).
- No significant correlations.

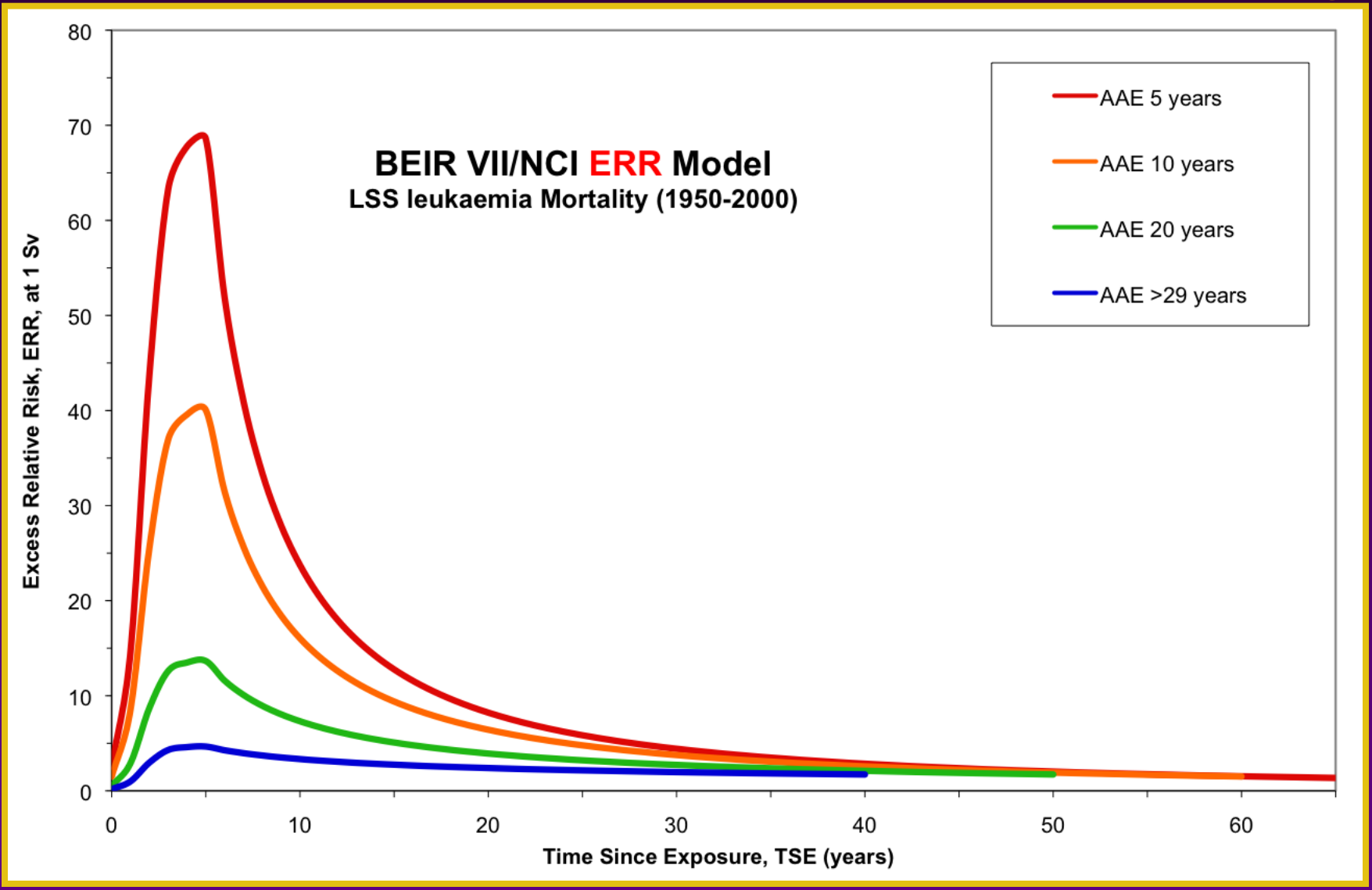
Cancer Risk in Kerala



Natural Background Radiation

- Perhaps a more focused investigation of the risk model-predicted effects of natural background radiation would be more informative?
- Childhood leukaemia has a predicted high ERR/Sv, but above a low background risk (1 in 1800 live births affected in economically developed countries).

BEIR VII/NCI Leukaemia Mortality



Natural Background Radiation

(Wakeford *et al., Leukemia* 2009; **23**: 770-6.
Little *et al. J Radiol Prot* 2009; **29**: 467-82.
Kendall *et al.*, *Leuk Res* 2011; **35**: 1039-43.)

- Recent risk models for radiation-induced leukaemia suggest that ~15% of cases of childhood (<15 years of age) leukaemia in Great Britain may be caused by natural background radiation.
  - red bone marrow dose ~1.4 mSv per annum
- Past epidemiological studies have been unable to reliably demonstrate this source of risk
  - probably have insufficient statistical power

Natural Background Radiation

(Little *et al. Radiat Res* 2010; **174**: 387-402)

- Power calculations show that *large* studies are required to detect the predicted excess risk
  - to achieve 80% power, >8000 cases are needed in a case-control or geographical correlation study covering the whole of Great Britain.
- Greatest effect is from γ-rays, not radon.
- The extensive data from the National Registry of Childhood Tumours (Childhood Cancer Research Group) make such a study feasible.

Natural Background Radiation

(Kendall *et al.*, *Leukemia* 2012, in press)

- First results from a large nationwide record-based case-control study of childhood cancer in Great Britain have been published.
- What would be expected from *prior evidence*?
  - Childhood leukaemia
    - A detectable positive effect of γ-radiation
    - No detectable effect of radon
  - Childhood cancers other than leukaemia
    - No detectable effect of either γ-radiation or radon

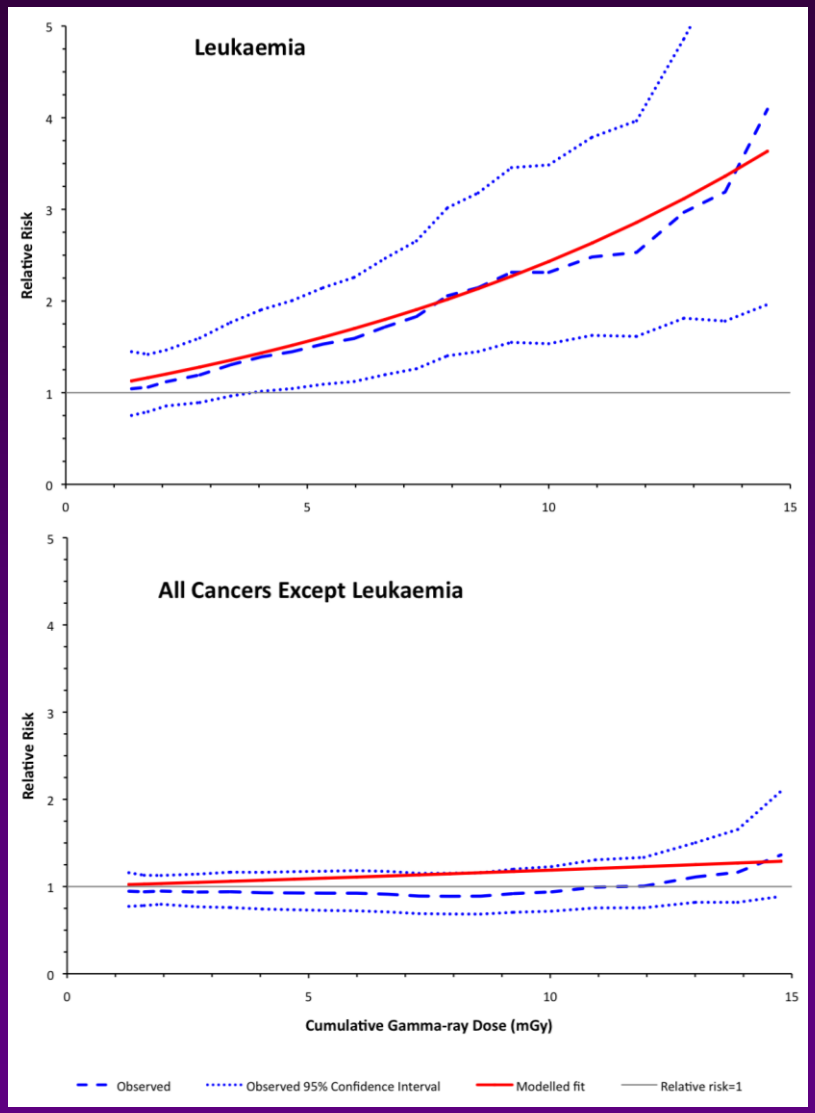
Case-control Study

(Kendall *et al.*, *Leukemia* 2012, in press)

- Case-control study of 27 500 childhood cancer cases and 37 000 matched controls.
- 9058 cases of childhood leukaemia matched with 11 912 controls.
- Cumulative (birth to diagnosis) exposures to background γ-radiation and radon estimated for maternal residence at birth of the child from nationwide radiation survey data.

Natural Background γ-radiation

Kendall *et al. Leukemia* 2012 (in press)



ERR/Gy = 120 (95% CI: 30, 220)

Kendall *et al.* (2012)

- For more information on this study please see relevant “poster” at this workshop, presented in Breakout Session 1A (during the afternoon of 13 September 2012).

Conclusions

- Studies of exposure to natural sources of radiation have provided important evidence to complement studies of man-made sources (e.g. the Japanese atomic-bomb survivors).
- Inhalation of radon (and its decay products) and lung cancer illustrates how important can be the contribution of these studies to our knowledge.

Conclusions

- Studies of populations living in high natural background radiation areas offer an opportunity to examine the effects of prolonged exposure to very low dose-rates.
- *However*, the power of studies of natural background radiation must be properly assessed, and such studies must be sufficiently large to be capable of providing meaningful evidence on radiation risks, otherwise interpretation is very difficult.

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