RADON AND THE LUNG CANCER
– A REAL EFFECT OR JUST AN ASSUMPTION?

Radon in the Environment 2015 Conference

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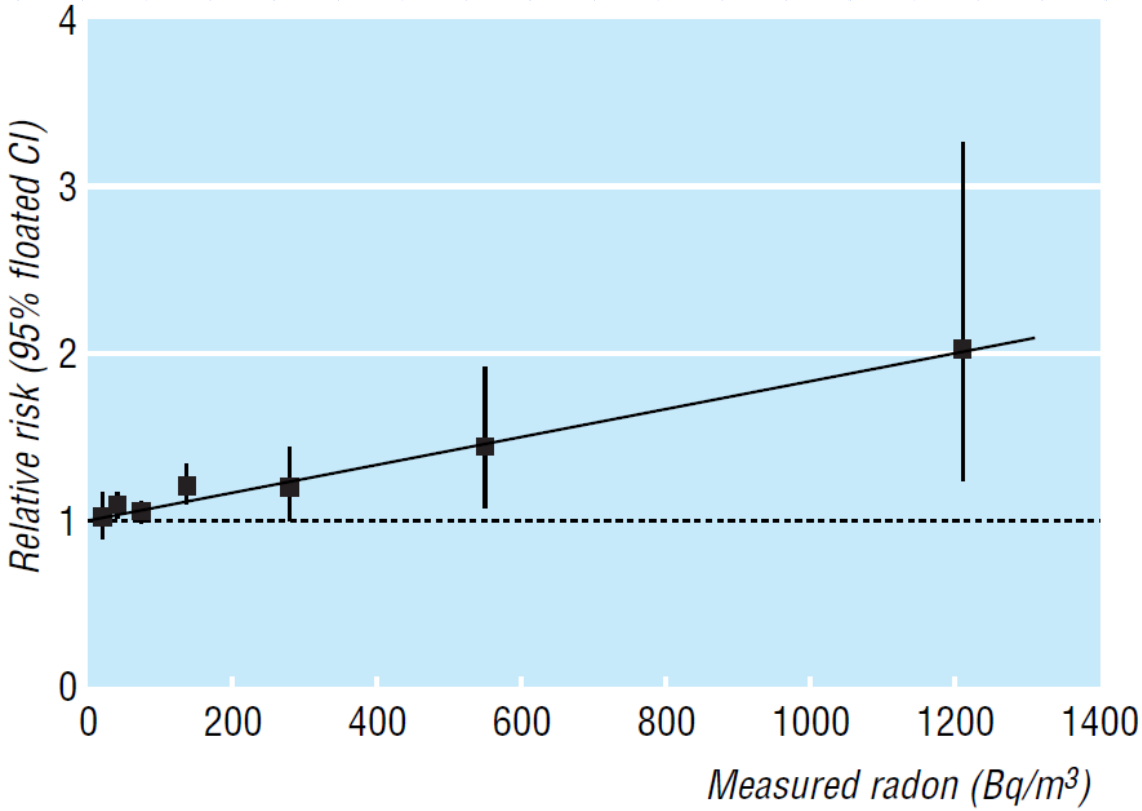
Radon risk

- Recent study from Sweden:
- *„Residential exposure to radon is considered to be the second cause of lung cancer after smoking"*
- *„Lung cancer risk was assumed to increase by 16 % per 100 becquerels per cubic meter (Bq/m^3) indoor air radon"*

- SOURCE: Axelsson G, Andersson EM, Barregard L. *Lung cancer risk from radon exposure in dwellings in Sweden: how many cases can be prevented if radon levels are lowered?* Cancer Causes Control (Springer), 2015, DOI 10.1007/s10552-015-0531-6

13 European studies

- Darby S. et al. *Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies*. British Medical Journal 330(7485):223-226; 2004



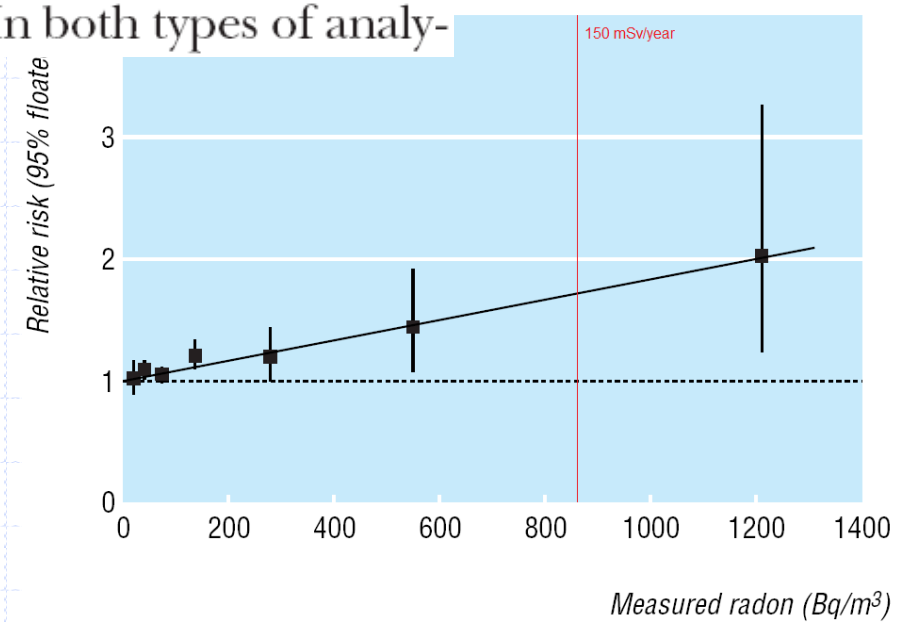
13 European studies

Statistical methods

We assessed the association between radon and lung cancer in two ways. Firstly, a model was fitted in which the risk of lung cancer was proportional to $(1+\beta x)$ where x is measured radon concentration and β the proportionate increase in risk per unit increase in measured radon. Secondly, we subdivided cases and controls by categories of measured radon concentration and plotted relative risks across different categories against estimated mean exposure levels in those categories. In both types of analy-

ERR [%/mSv/year] =

$$= 0.47^{+0.42}_{-0.31}$$



13 European studies

Results:

Risk of lung cancer versus measured radon concentration

After we stratified for study, age, sex, region of residence, and smoking the risk of lung cancer increased by 8.4% (95% confidence interval 3.0% to 15.8%; P = 0.0007) per 100 Bq/m^3 increase in measured radon concentration. We stratified for

Initial assumption:

Statistical methods

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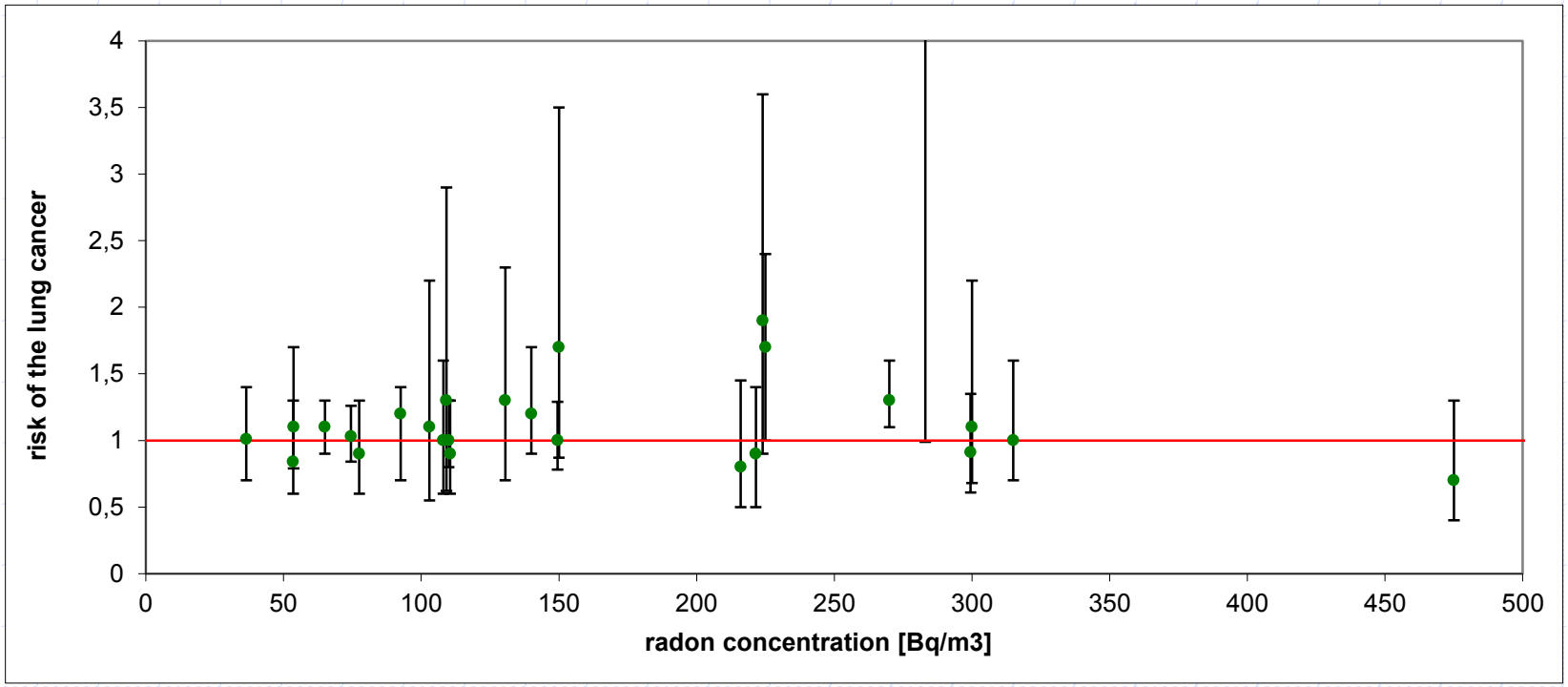
13 European studies

- The authors selected a linear model to process the data, which are very uncertain, and then showed that the data fit the linear model that they assumed
- There are also other models that would fit the widely scattered data.
  But they were not tested

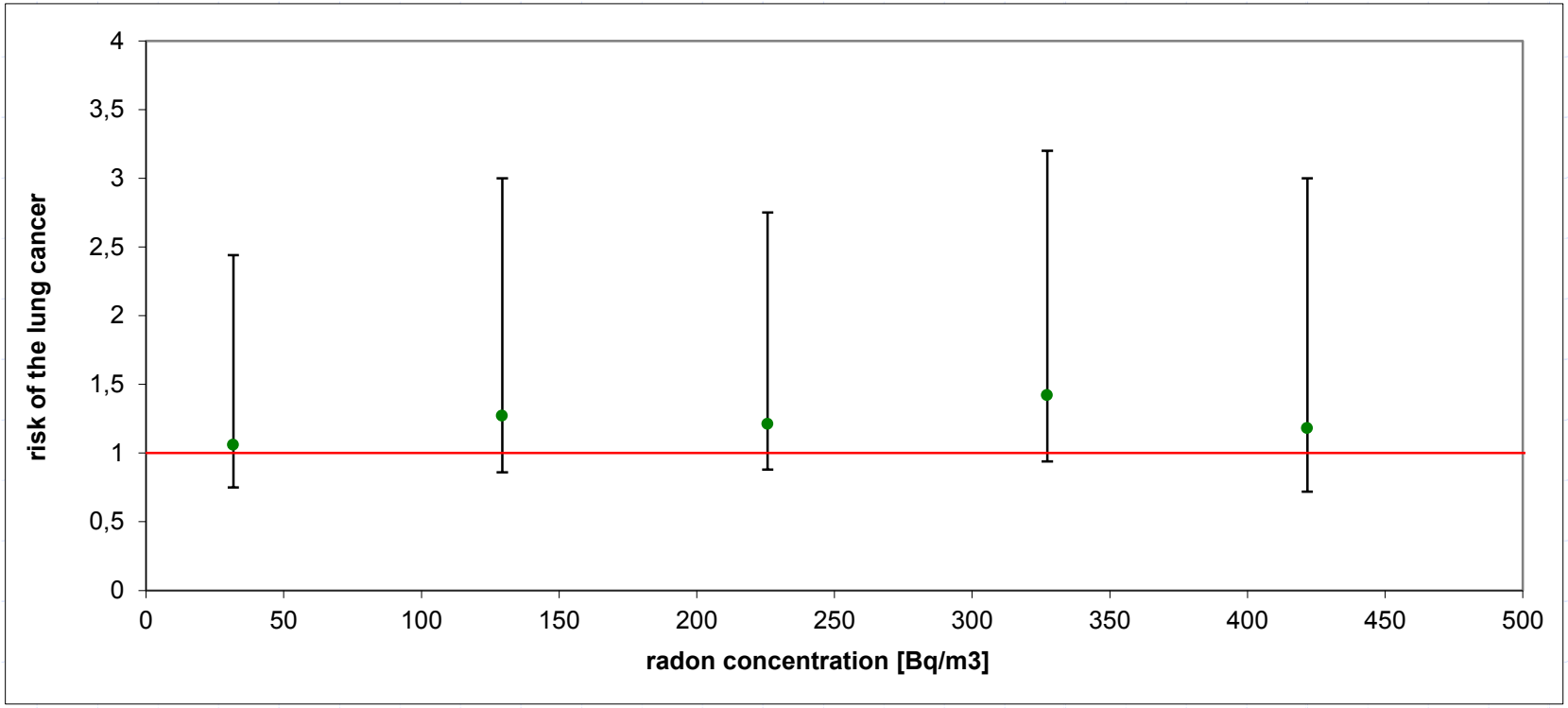
Other studies with the linear assumption

- Lubin JH and Boice JD. *Lung Cancer Risk From Residential Radon: Meta-analysis of Eight Epidemiologic Studies*. J Natl Cancer Inst 89:49–57; 1997



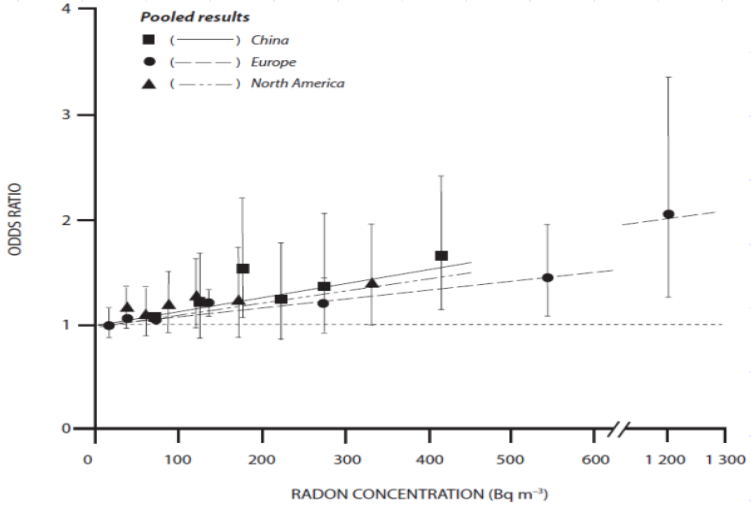
Other studies with the linear assumption

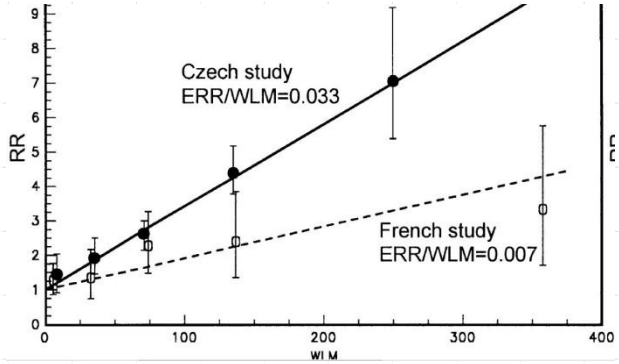
- Lubin JH et al. *Estimating lung cancer mortality from residential radon using data for low exposures miners*. Radiat Res 147:126-134; 1997.



Other studies with the linear assumption

- UNSCEAR 2000
- and many others





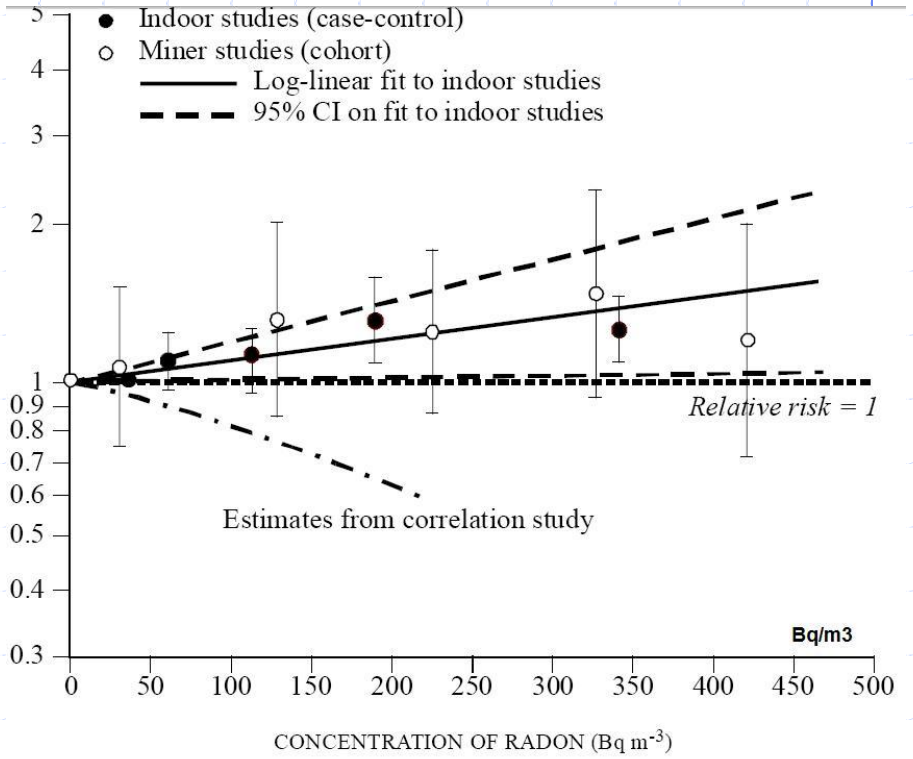


Figure II. Risk estimates of lung cancer from exposure to radon (based on [L21]).
Shown are the summary relative risks from meta-analysis of eight indoor radon studies and from the pooled analysis of underground miner studies, restricted to exposures under 50 WLM [L22] and the estimated linear relative risk from the correlation study of Cohen [C18].

Assumption of the linearity

- According to the linear no-threshold (LNT) hypothesis, the excess risk increases linearly vs. Bq/m^3 (or vs. mSv effective dose) from zero to the maximum. However, there are no data that support the validity of this hypothesis over the whole range of doses

The „zero radon environment”

- Many authors widely use the value “0 Bq/m^3”, as a background for linear extrapolation of their results
- However, there is no place on earth without the concentration of radon, and epidemiological data with “zero” dose from radon does not exist
- There is no empirical confirmation of any extrapolation from high doses or concentrations down to zero radon level
- All assumptions based on 0 Bq/m^3 make no sense

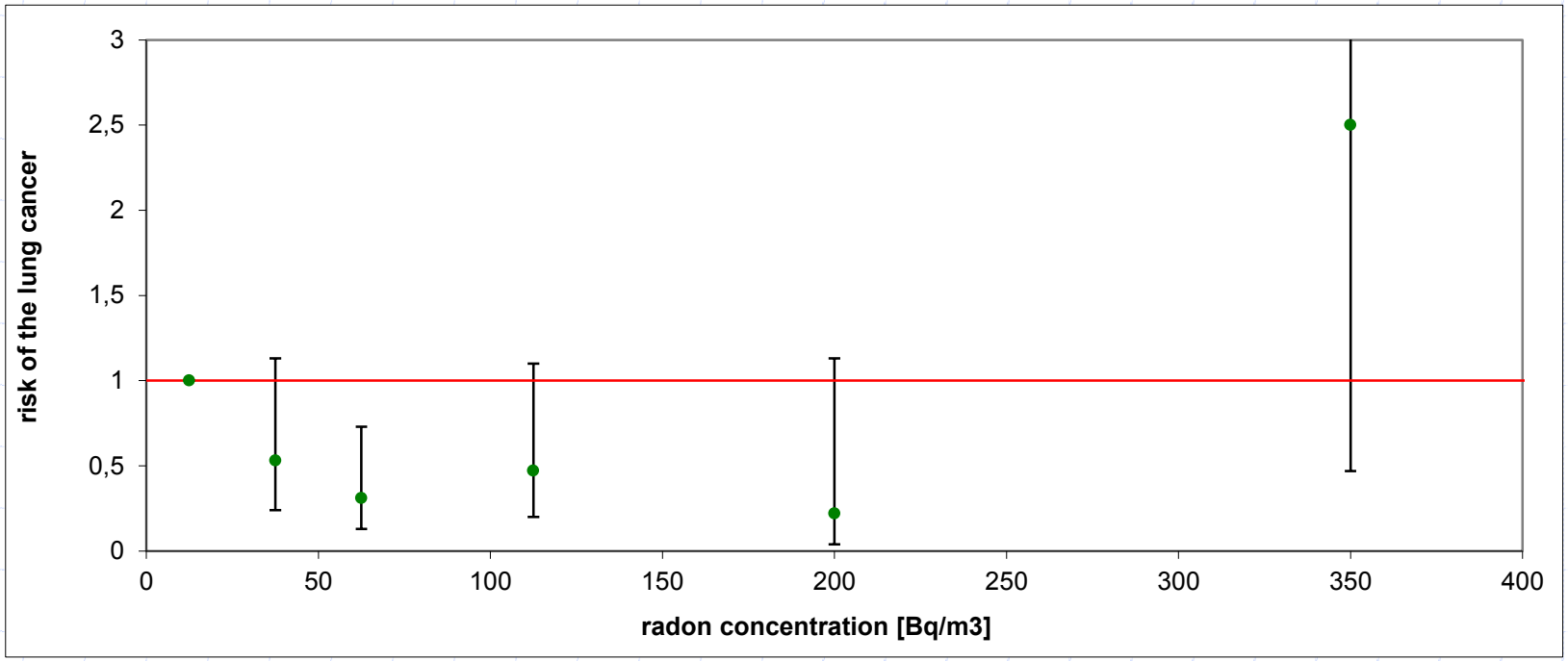
Non-linear studies

- Many studies show no correlation or even a negative correlation between lung cancer and low radon concentration

- Thompson RE, Nelson DF, Popkin JH, Popkin Z. *Case-control study of lung cancer risk from residential radon exposure in Worcester County, Massachusetts*. Health Physics 94(3):228–241; 2008
- Cohen BL. *Test of the Linear No-Threshold Theory of radiation carcinogenesis for inhaled radon decay products*. Health Phys 68(2):157-174; 1995
- Conrady J and Martin K. *Weniger Modelle – spezifischere analytische Studien zum Radonrisiko in Wohnungen sind notwendig*. Bundesgesundheitsblatt 19:106–110; 1996 (in German)
- Becker K. *Health Effects of High Radon Environments in Central Europe: Another Test for the LNT Hypothesis?* Nonlinearity Biol Toxicol Med 1(1):3–35; 2003

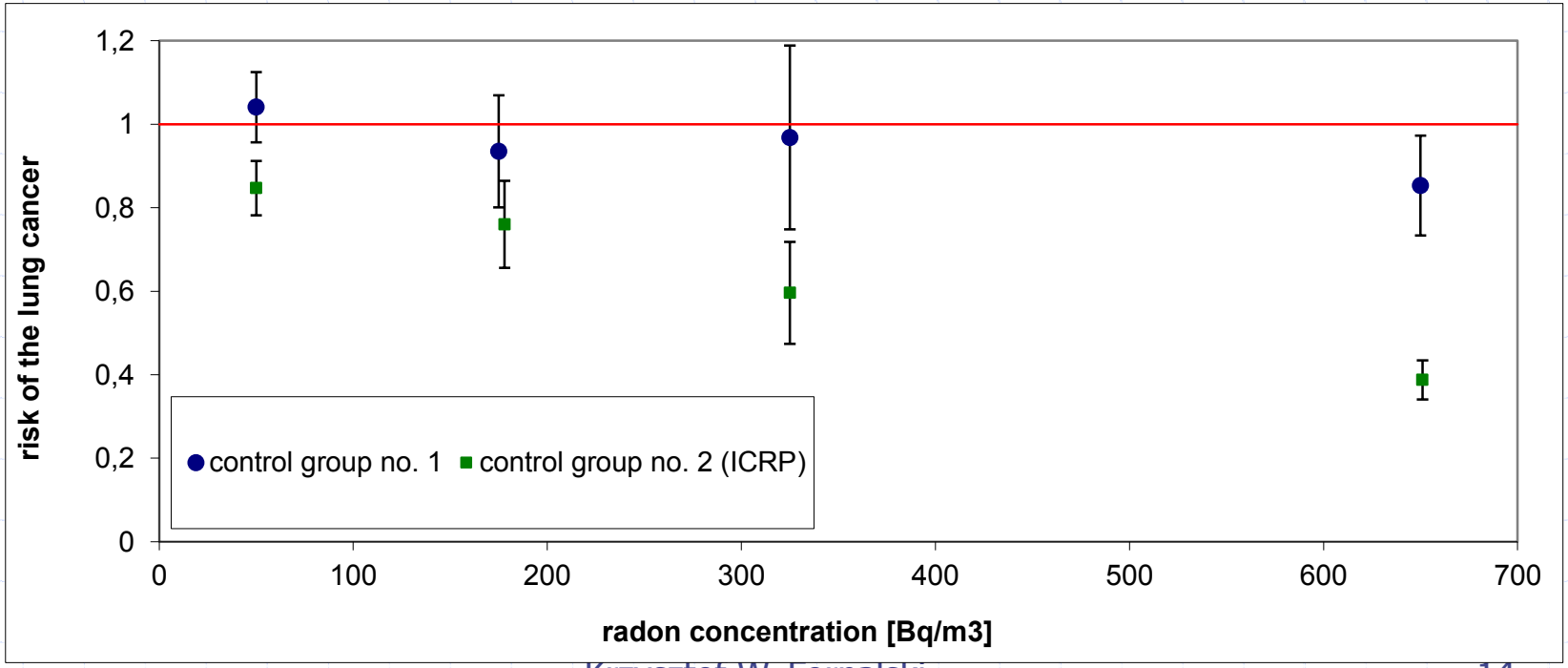
Thompson et al. 2008

- Thompson RE, Nelson DF, Popkin JH, Popkin Z. *Case-control study of lung cancer risk from residential radon exposure in Worcester County, Massachusetts*. Health Physics 94(3):228–241; 2008



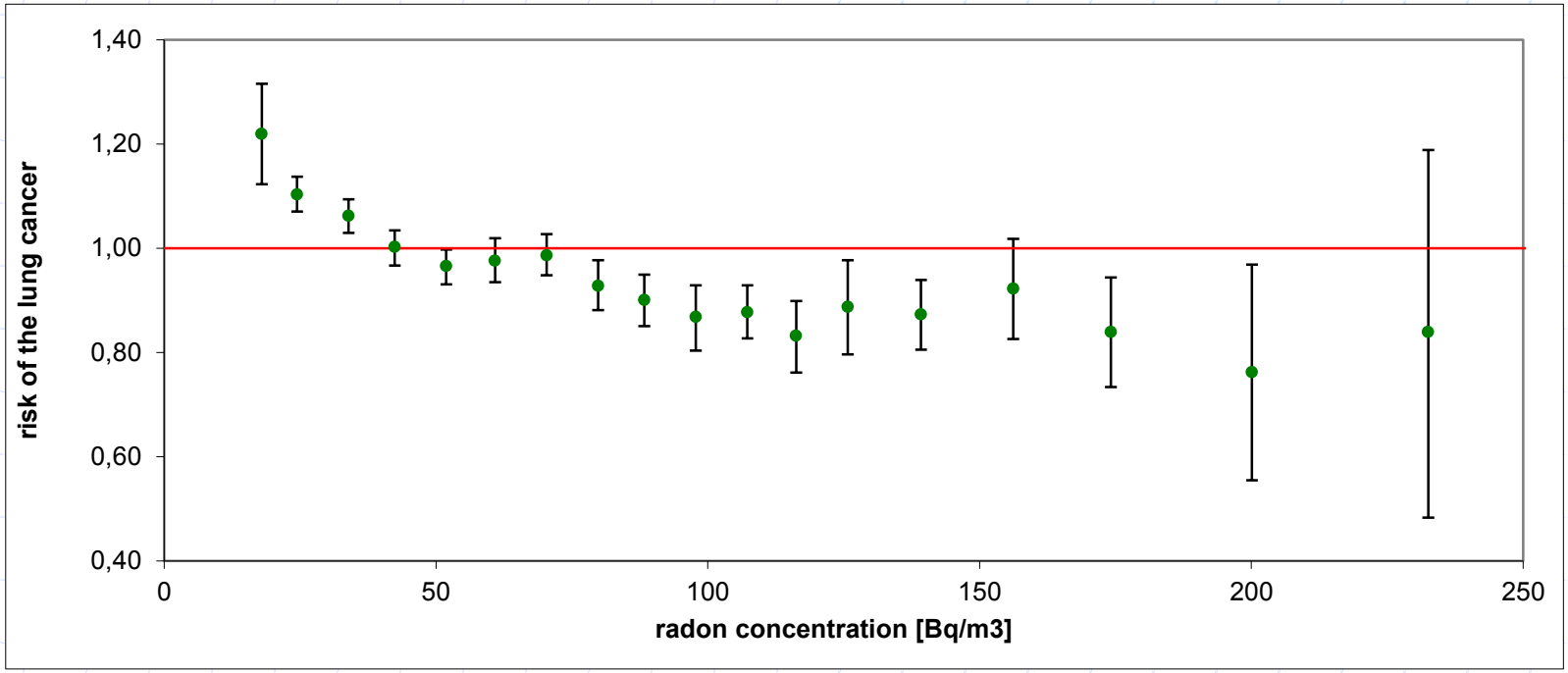
German study

- Conrady J and Martin K. *Weniger Modelle – spezifischere analytische Studien zum Radonrisiko in Wohnungen sind notwendig*. Bundesgesundheitsblatt 19:106–110; 1996 (in German)
- Becker K. *Health Effects of High Radon Environments in Central Europe: Another Test for the LNT Hypothesis?* Nonlinearity Biol Toxicol Med 1(1):3–35; 2003



Cohen study

- Cohen BL. *Test of the Linear No-Threshold Theory of radiation carcinogenesis for inhaled radon decay products*. Health Phys 68(2):157-174; 1995



Joint re-analysis of 28 studies

- 28 independent radon studies taken into account in one meta-analysis
- Bayesian robust statistical method was used
- 7 models were fitted to the data

- Fornalski KW and Dobrzyński L. *Pooled Bayesian analysis of twenty-eight studies on radon induced lung cancers*. Health Physics, vol. 101, no. 3, pp. 265-273; 2011

Joint re-analysis of 28 studies

- Model 1 – $RR = 1$,
- Model 2 – $RR = a$, where a denotes a constant to be fitted,
- Model 3 – $RR = a + bD$, where a and b are fitting parameters, and D denotes the annual dose,
- Model 4 – $RR = 1 + bD$, differs from Model 3 by setting the parameter a to 1,
- Model 5 – same as Model 4 but with the parameter b constrained to the positive values (LNT model),
- Model 6 – $RR = a + bD + cD^2$ with a, b and c being fitting parameters,
- Model 7 - $RR = 1 + bD + cD^2$, i.e. same as Model 6 but with the parameter a set to 1.

Joint re-analysis of 28 studies

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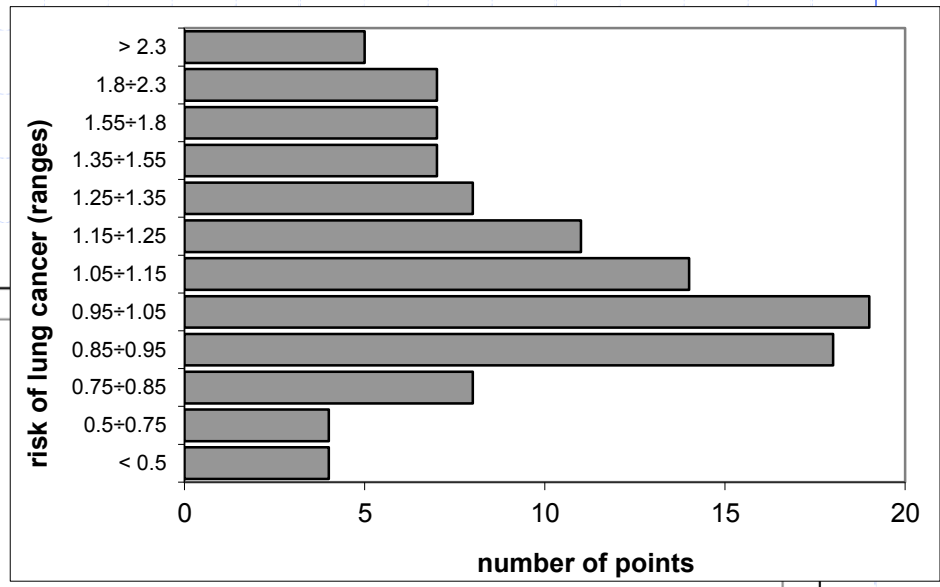

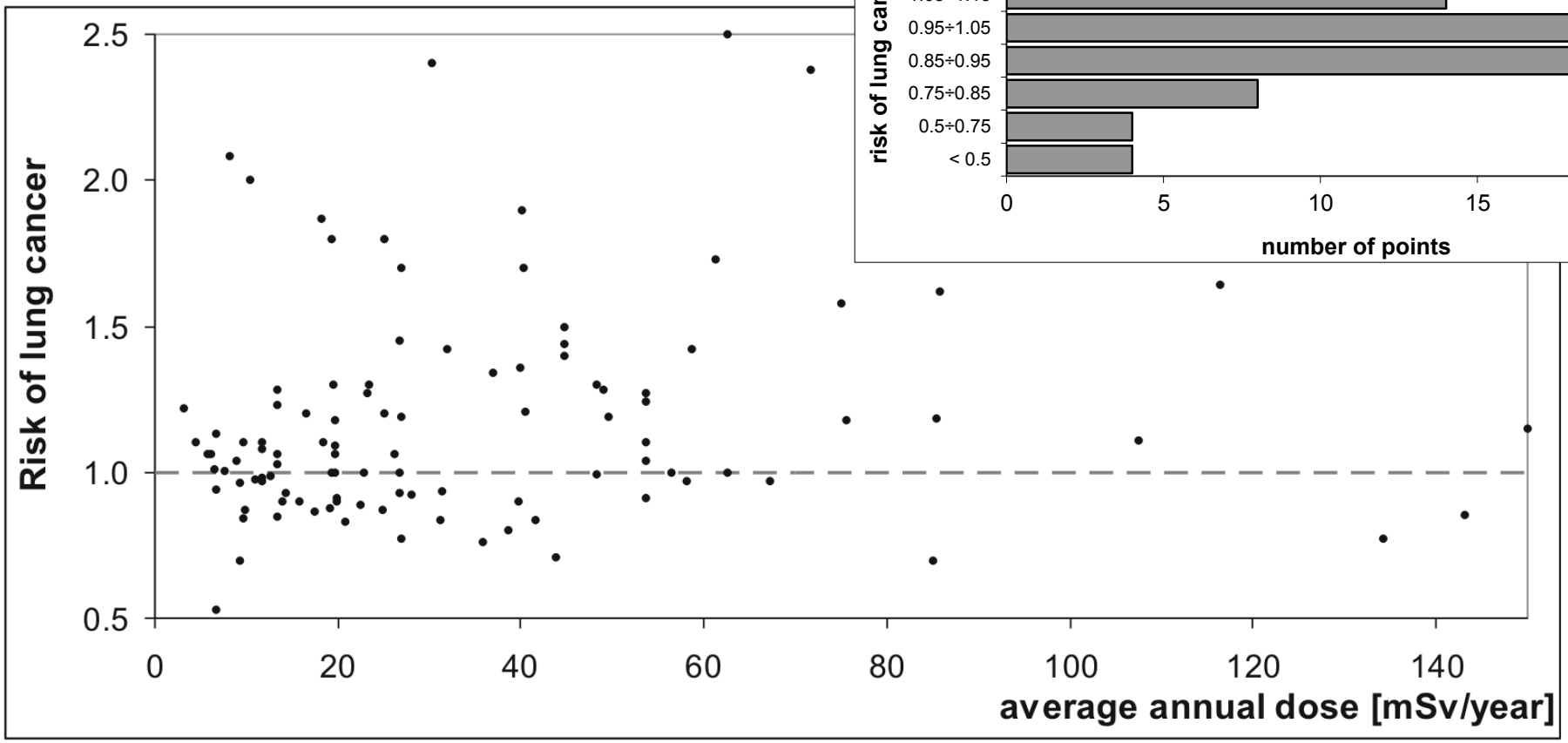

Joint re-analysis of 28 studies

- Two analysed low dose ranges:
  - up to 70 mSv/year (391 Bq/m^3)
  - up to 150 mSv/year (838 Bq/m^3)
    - 1 Bq/m^3 → 0.179 mSv/year to lungs
      source: (UNSCEAR 2006, Annex E, Table 25)
- Full analysis with 28 studies
- Narrowed analysis with 26 studies
  - Cohen's and miners' data excluded

Results

- Assuming linear (LNT) dependence:
  - 28 studies, <150 mSv/y: ERR = (0.11 ± 0.03) %/mSv/y
  - 26 studies, <150 mSv/y: ERR = (0.19 ± 0.03) %/mSv/y
  - 28 studies, <70 mSv/y: ERR = (0.13 ± 0.03) %/mSv/y
  - 26 studies, <70 mSv/y: ERR = (0.43 ± 0.16) %/mSv/y
    - This one similar to Darby et al.: ERR = 0.47 %/mSv/year
- However, using robust statistics, the most probable model is constant one (Model 1) ➔ no risk in analysed range

Results

- No risk is a final result irrespective of the data used
  - range up to 70 or 150 mSv/year
  - 26 or 28 studies
- Model 1 can correspond to the threshold dose-response curve

Conclusions

- The pooled Bayesian analysis of 28 radon studies shows that there is no evidence for lung cancer risk increase in low dose range
- To accept the linear no-threshold (LNT) model, one should *a priori* have higher degree-of-belief in such relationship than in a dose-independent model
- The widely presented increase in lung cancer due to low concentrations of radon is not a real effect; it is an assumption only

Thank you!

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