Pooled Bayesian Analysis of 28 Studies on Radon Induced Lung Cancers

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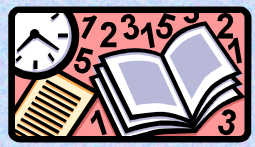
Abstract



The influence of ionizing radiation of radon-222 and its daughters on lung cancer risks that were published in 28 papers was re-analyzed using seven alternative dose-response models. The risks of incidence and mortality was studied in two ranges of low annual radiation dose: 0-70 mSv per year (391 Bq m^{-3}) and 0-150 mSv per year (838 Bq m^{-3}). Assumption-free Bayesian statistical methods were used. The analytical results demonstrate that the published incidence and mortality data do not show that radiation dose is associated with increased risk in this range of doses. This conclusion is based on the observation that the model assuming no dependence of the lung cancer induction on the radiation doses is at least ~90 times more likely to be true than the other models tested, including the Linear No-Threshold (LNT) model.

Convertion factor from radon concentration to effective dose on lungs:

1 Bq/m^3 = 0.179 mSv/year

(based on UNSCEAR Report 2006, Annex E, Table 25)

The following models were fitted to the data and tested:

- 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. This model is called "linear 1",
- Model 4 – RR = 1 + bD, which is called "linear 2" and differs from "linear 1" by setting the parameter a to 1,
- Model 5 – same as "linear 2" 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. This model is called "quadratic 1",
- Model 7 - RR = 1 +bD + cD^2, i.e. same as "quadratic 1" but with the parameter a set to 1 ("quadratic 2").

Methods

Bayesian methods were used to fit all functions of 7 models. The probability of getting datum E in a single measurement is:

$$P(E|\sigma) = \frac{1}{\sqrt{2\pi}\sigma}\exp\left[-(T-E)^2/(2\sigma^2)\right]p(\sigma)$$

Function $p(\sigma)$ is a prior probability density function of the uncertainty σ in the experimental datum E. It is convenient to use the following form of this prior function:

$$p(\sigma) = \frac{\sigma_0}{\sigma^2} \quad \text{and } \sigma \geqslant \sigma_0$$

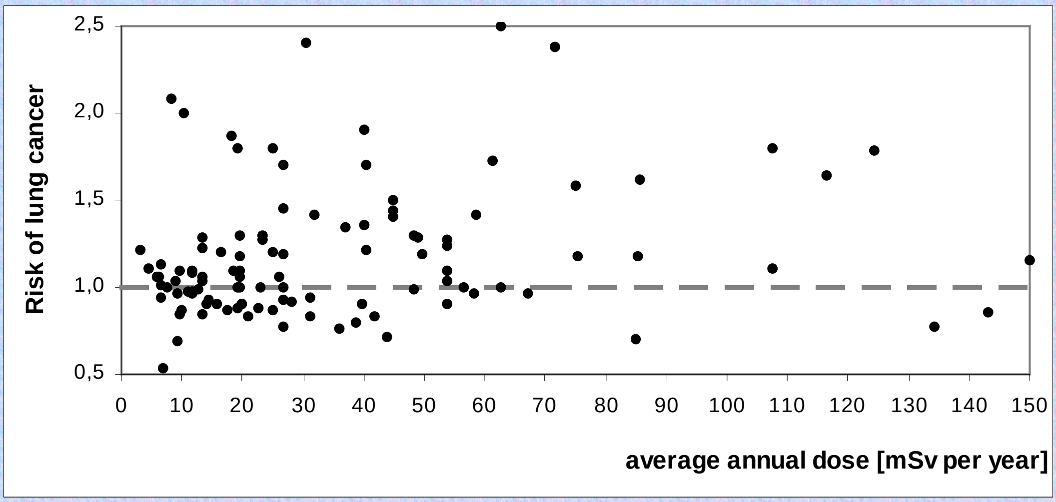
Two functions were compared using model selection algorithm, where the posterior probability of each of them equals

$$N_{Wm}(M) = \frac{\sum_{i=1}^{N} \frac{1}{(T_{Mi}-E_i)^2}\left[1-\exp\left(-\frac{(T_{Mi}-E_i)^2}{2\sigma_{0i}^2}\right)\right]}{\prod_{\alpha=1}^{n} \frac{\alpha_{\max}^{(M)}-\alpha_{\min}^{(M)}}{\sigma_{\alpha}^{(M)}\sqrt{2\pi}}}$$

where T represents expected data, and α_{max} and α_{min} are expected maximal/minimal possible values of analysed parameter.

Data

The figure below presents the data points from 28 popular radon studies (see table on right) altogether. The points do not contain the uncertainty ranges because of readability. However, the uncertainties are usually large.



Country/region/group	Source
Austria	(Oberaigner et al. 2002)
Canada, Winnipeg	(Letourneau et al. 1994)
China, Gansu	(Wang et al. 2002)
China, Shenyang	(Blot et al. 1990)
Czech Rep.	(Tomášek et al. 2001)
England, south-west	(Darby et al. 1998)
Finland I	(Auvinen et al. 1996)
Finland II	(Ruosteenoja 1991)
Finland III	(Ruosteenoja et al. 1996)
France	(Baysson et al. 2004)
Germany	(Wichmann et al. 2005)
Germany, Saxony	cited in (Becker 2003)
Germany, Schneeberg	(Conrady et al. 2002)
Germany, western	(Kreienbrock et al. 2001)
Italy, Mediterranean	(Bochicchio et al. 2005)
Italy, Alps	(Pisa et al. 2001)
Japan, Misasa	(Sobue et al. 2000)
Uranium miners	(Lubin et al. 1997b) cited in (UNSCEAR 2000)
Spain	(Barros-Dios et al. 2002)
Sweden I	(Lagarde et al. 2001)
Sweden II	(Pershagen et al. 1992)
Sweden III	(Pershagen et al. 1994)
USA	(Cohen 1995)
USA, Iowa	(Field et al. 2000)
USA, Missouri I	(Alavanja et al. 1994)
USA, Missouri II	(Alavanja et al. 1999)
USA, New Jersey	(Schoenberg et al. 1990)
USA, Worcester	(Thompson et al. 2008)

Results

The analysis for Model 2 gives an average risk ratio (RR) equal to 97.6 $\pm$ 0.3%. For the linear Models 3 and 4, in all studied cases the risk decreases with increasing dose. However, if one forces in Model 5 the LNT assumption, the value of the obtained slope is b = 0.0011 $\pm$ 0.0003. For the quadratic Models 6 and 7 one obtains a hormetic-type curve with the threshold at 140 mSv y^{-1} (782 Bq m^{-3}) and the maximal reduction (13$\pm$7)% of lung cancer incidences at 73 mSv per year (408 Bq m^{-3}). No significant increase of risk is observed below 8 mSv per year (45 Bq m^{-3}).

The model selection algorithm shows that the Model 1, which assumes *RR* = 100% independently of the dose, turns out to be 237 times more likely than Model 2 which allows *RR* to take arbitrary constant values. It is also 90 times more likely than the LNT model. The quadratic models are least likely.

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