XLNT Foundation Designates January as Radon Health Benefits Awareness Month

XLNT Foundation hereby declares January as Radon Health Benefits Awareness Month, in order to bring the attention of the public to the beneficial health effects of residential radon.

XLNT Foundation website: http://www.x-lnt.org/

The XLNT Foundation is a nonprofit, tax-exempt charitable organization (EIN 47-5558924) under Section 501(c)(3) of the Internal Revenue Code.

Document ID: RHBAM-V1.0c dated 1/20/2017

Health Effects of Radon - Currently Accepted View

- Exposure to high levels of radon in underground miners has been observed to result in increased lung cancers*
- It is generally assumed that even low levels of radon, such as found in homes, can increase lung cancer risk, with no threshold below which there is no risk.
- This is based on the linear no-threshold (LNT) model for radiation-induced cancers
- This view is endorsed by a large number of advisory bodies, regulatory agencies, professional organizations, etc.

*Note: Radiation dose due to radon and its decay products are primarily to the lungs.

Criticism of Currently Accepted View on the Health Effects of Radon

- Does it make sense to extrapolate observed health effects from very high radon levels (in mines) to low levels (in homes) linearly? E.g., can we estimate the health effect of taking a single sleeping pill by studying the results from taking 50, 100, or 150 sleeping pills, and extrapolating down to a single sleeping pill? Of course not. However, such logic has been used by advisory bodies in advocating the use of the LNT model.
- Thus, though currently accepted by the scientific community, the current views on the health effects of residential radon need to be examined to determine whether these views are consistent with evidence.

Preamble Regarding the Radon "Problem"

US Environmental Protection Agency (EPA) says (in its website):

Radon is the number one cause of lung cancer among non-smokers, according to EPA estimates. Overall, radon is the second leading cause of lung cancer. Radon is responsible for about 21,000 lung cancer deaths every year.

"EPA believes that any radon exposure carries some risk—no level of radon is safe." says A Citizen's Guide to Radon by EPA, May 2012

"EPA recommends that you take action to reduce your home's indoor radon levels if your radon test result is 4 pCi/L or higher."

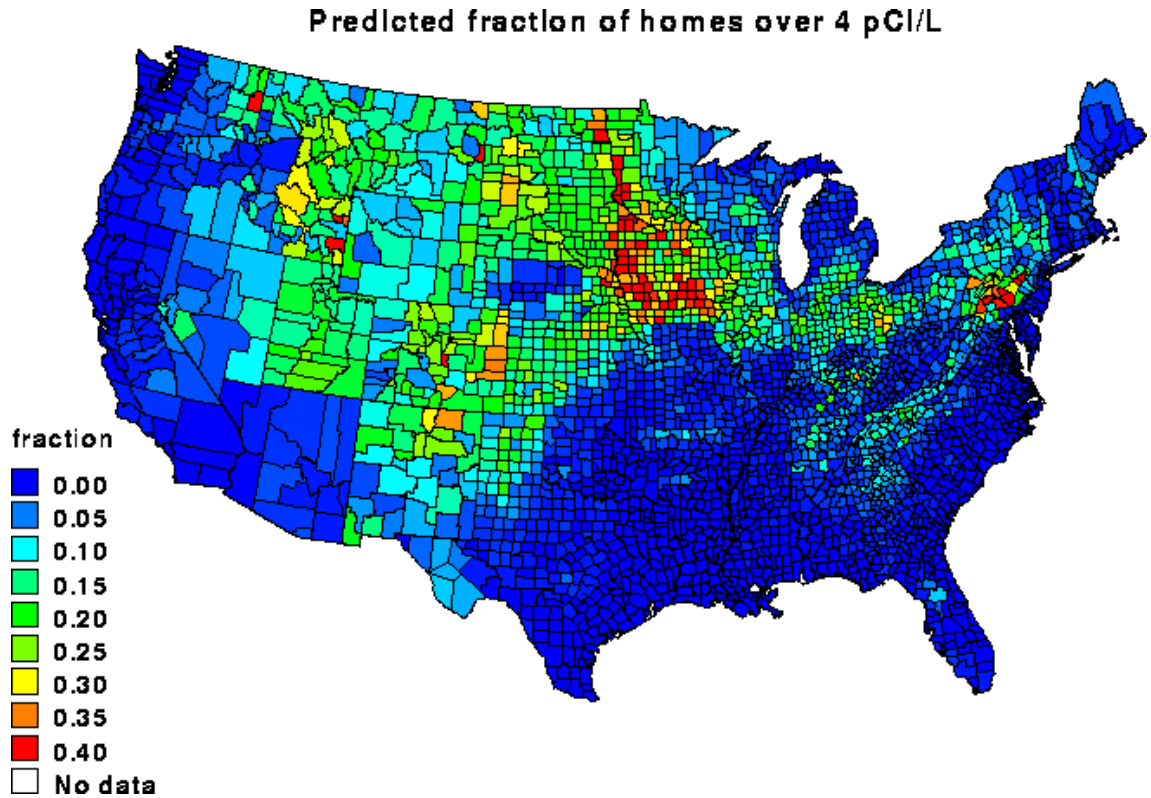
and

"Keep in mind that radon levels below 4 pCi/L still pose some risk and that radon levels can be reduced to 2 pCi/L or below in most homes." says Home Buyer's and Seller's Guide to Radon by EPA, September 2013 (revised)

EPA has designated January as National Radon Action Month https://www.epa.gov/radon/national-radon-action-month-consumer-information and urges the public to take action to protect themselves from the risks due to radon.

Now let us examine what the evidence says about the effect of residential radon on lung cancer.

Predicted Fraction of Homes Over Radon Levels of 4 pCi/L

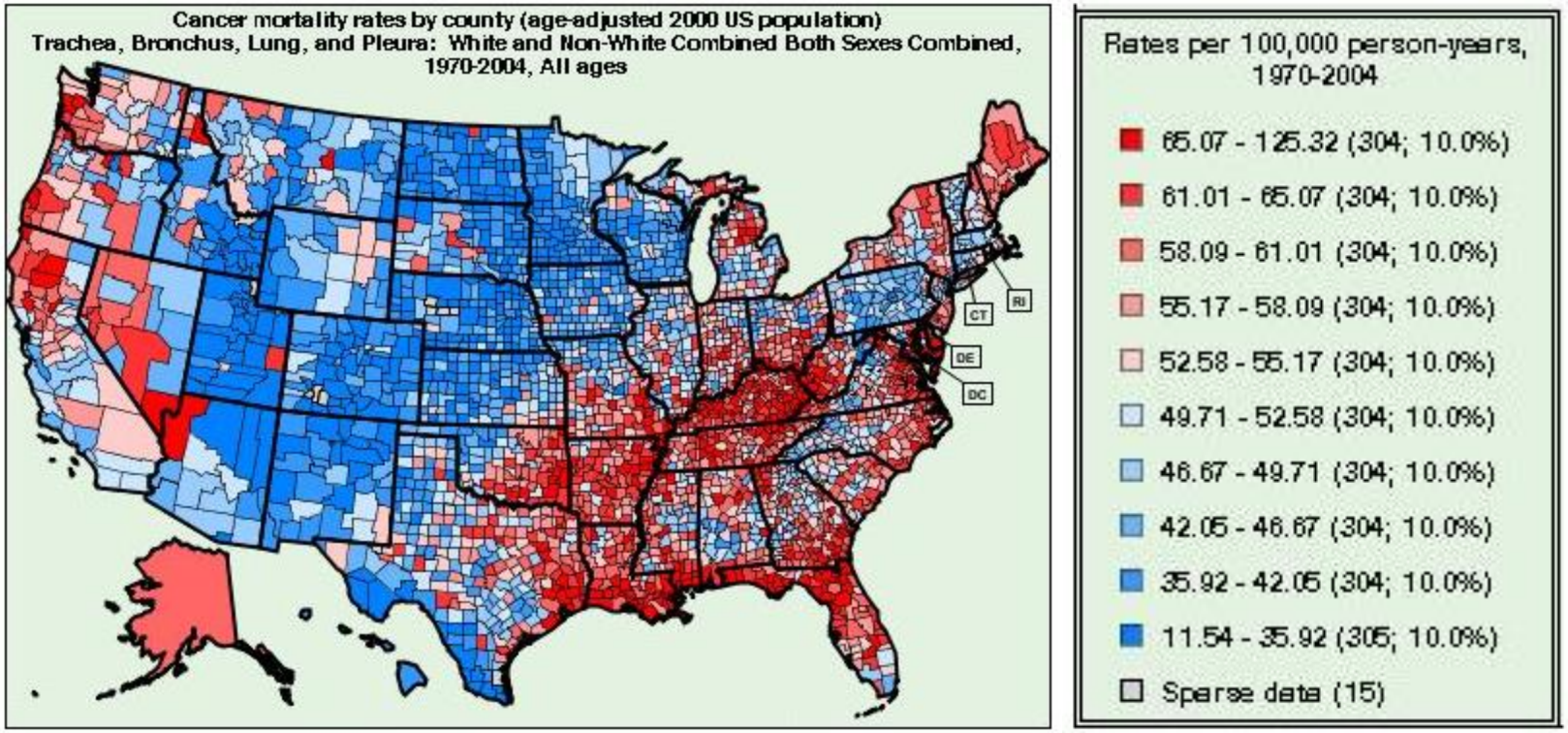


Predicted Fraction of homes over 4 pCi/L of Radon (from LBL):
http://www2.lbl.gov/Science-Articles/Archive/radon-risk-website.html

Radon levels vary widely in the USA, as seen in the map above.

Based on EPA's guidance, we would expect to see higher rate of lung cancers in the higher radon areas colored green, yellow, and red in the above map.

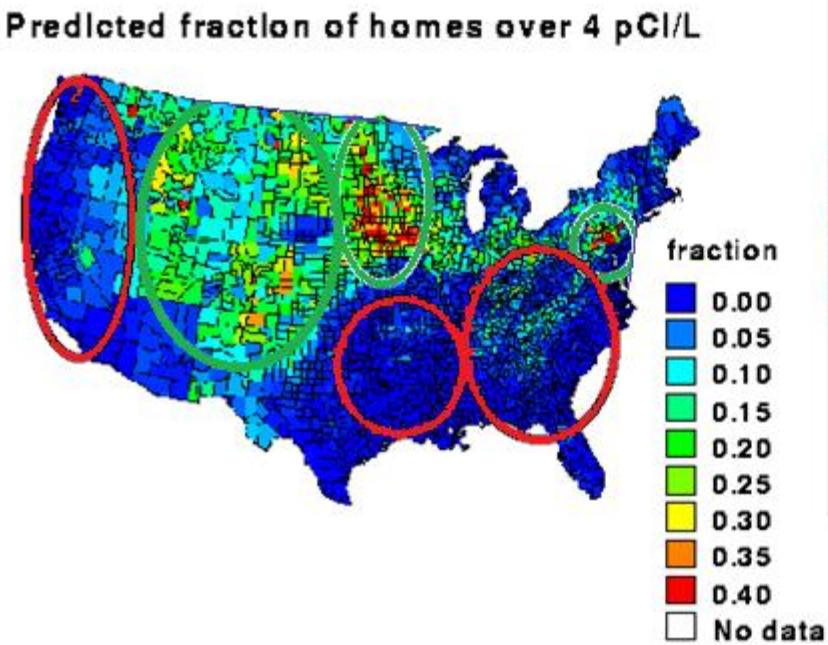
Lung Cancer Mortality Rates in the USA (1970-2004)

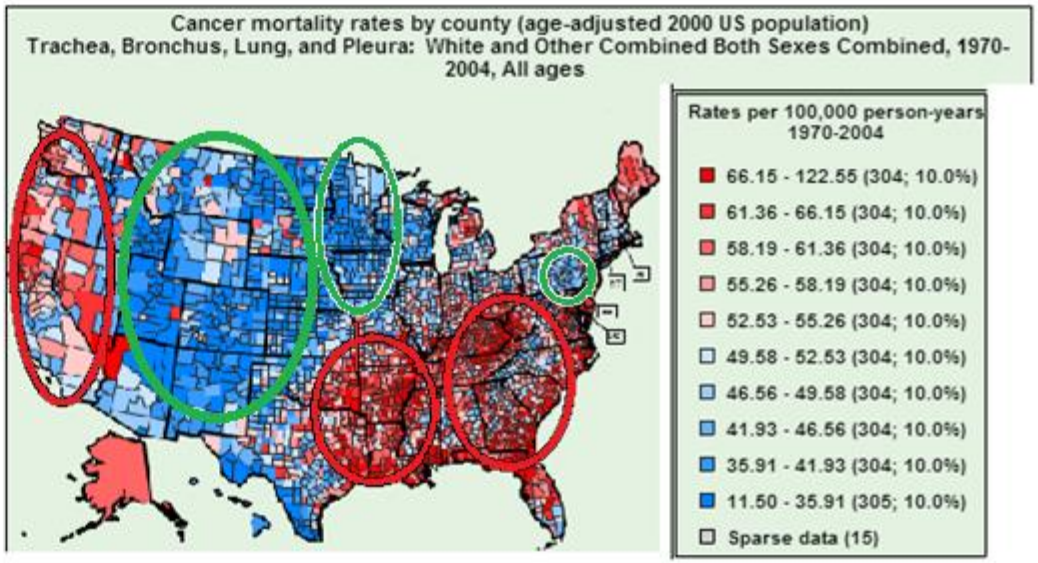


From: https://ratecalc.cancer.gov/ratecalc/

Lung Cancer Rates vary widely across the USA

Radon Levels and Lung Cancer in USA

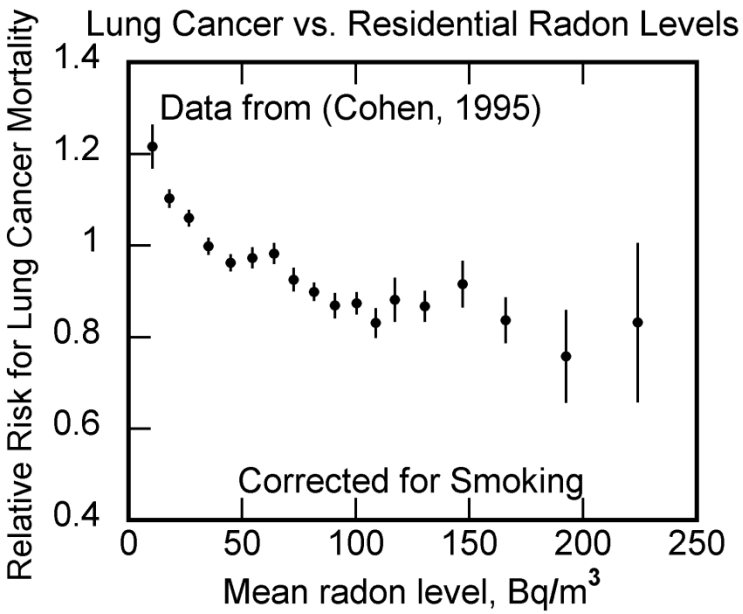




Higher radon counties (green, yellow, red) correspond to mostly lower rates of lung cancer (blue). Higher lung cancer counties (red) correspond mostly to lowest radon areas (blue).

Radon levels: https://en.wikipedia.org/wiki/File:US_homes_over_recommended_radon_levels.gif
Lung, Trachea, bronchus, pleura cancer mortality: http://ratecalc.cancer.gov/ratecalc/

Residential Radon and Lung Cancer



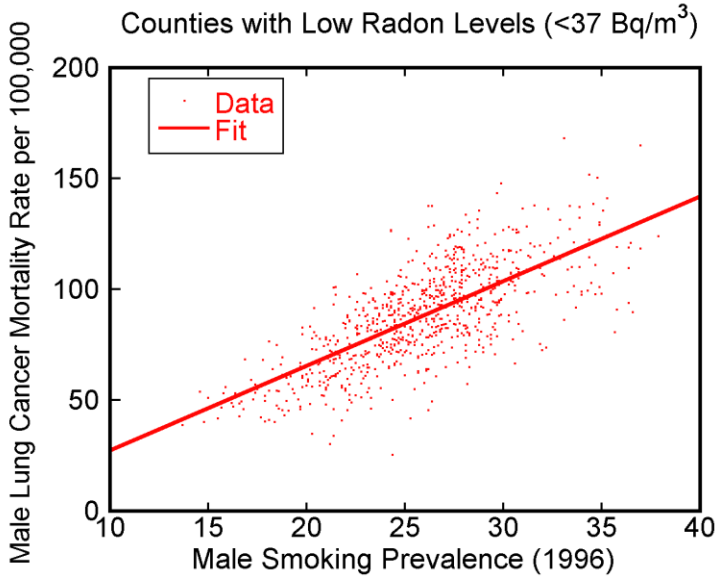
Smoking data at County level were not available. State level data were used to estimate County level data based on demographics to correct for smoking. Led to uncertainties.

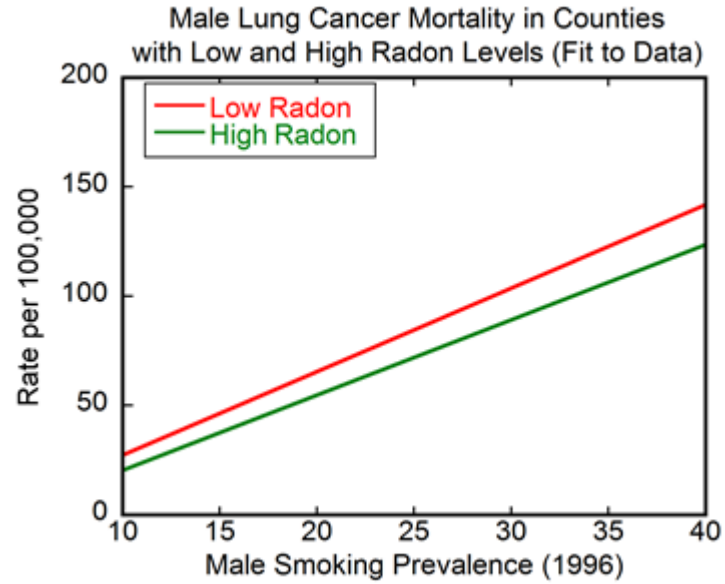
Cohen study was criticized for incorrect accounting of smoking (Heath, 2004)
Strong negative correlations found for cancers strongly linked to smoking – indicates likely confounding by smoking (Puskin, 2003)

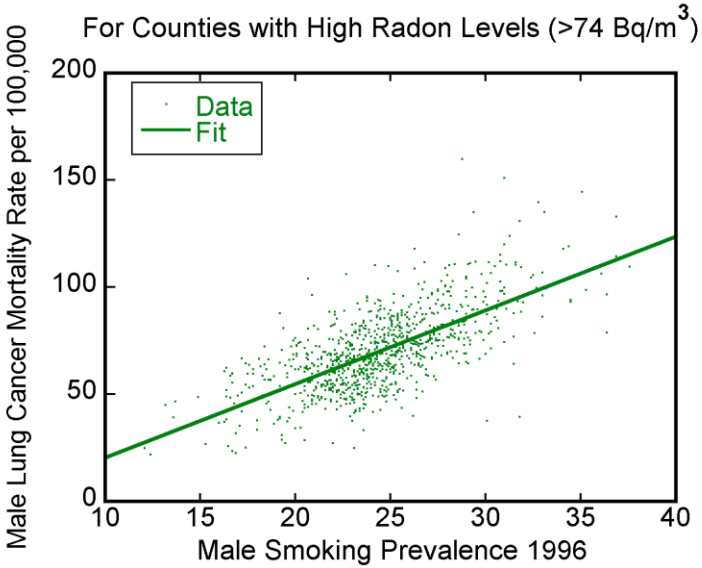
County level smoking prevalence data are now available, e.g.:
Cigarette smoking prevalence in US counties: 1996-2012, (Dwyer-Lindgren, 2014)

Note regarding units for radon levels. The traditional unit is pCi/L. The SI unit for radon levels is Bq/m^3. The relationship between the two units is: 1 pCi/L = 37 Bq/m^3.

Lung Cancer Mortality Rate (2000-2009) vs. Smoking Prevalence in 1996 for Males in Low and High Radon Counties of USA





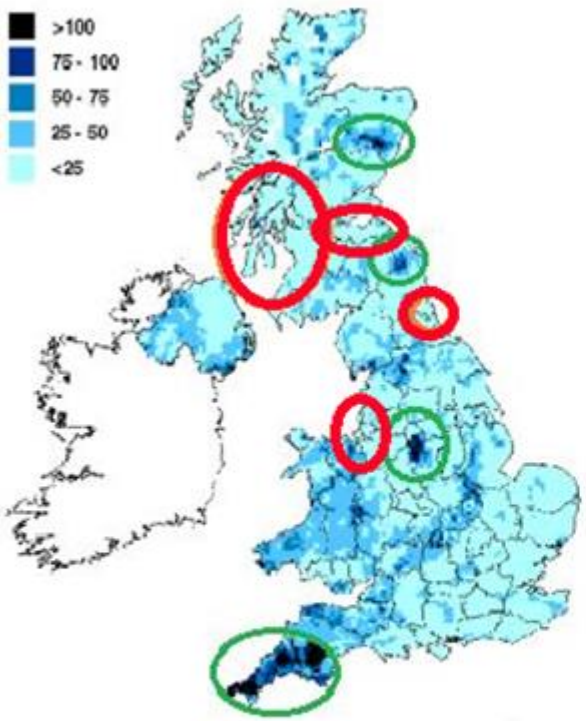


Radon levels from: USEPA 1993b. EPA/State Residential Radon Surveys, 1987-1992, Volumes 1-5.: U.S. Environmental Protection Agency.
Lung cancer mortality rates from: https://gis.cancer.gov/geoviewer/app/

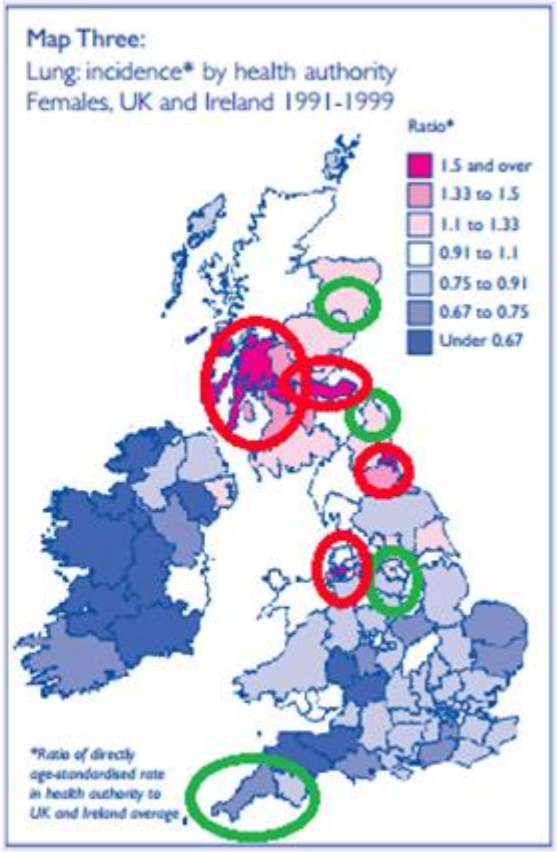
Lung cancer mortality rates are lower in high radon counties in comparison to low radon counties for the same level of smoking.

Therefore, confounding by smoking cannot explain the reduction of lung cancers observed in high radon counties.

Radon Levels and Lung Cancer in UK



Geometric mean radon, Bq m^{-3}



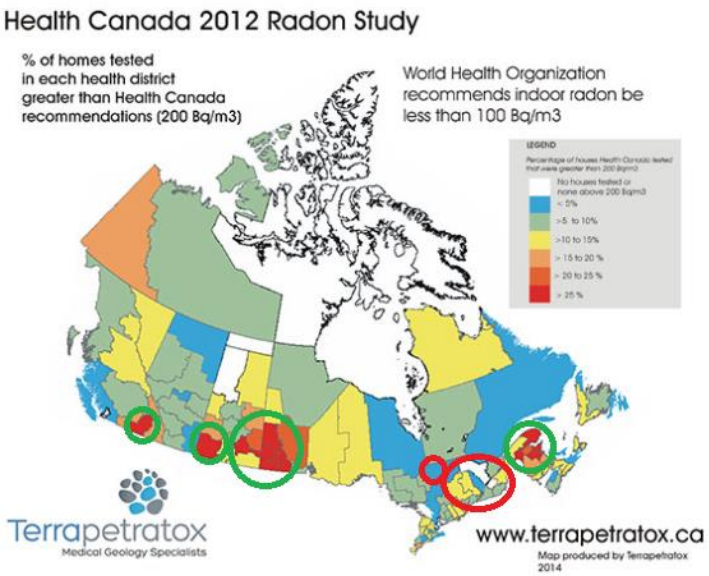
Age-Adjusted Lung Cancer Incidence Ratio to Average

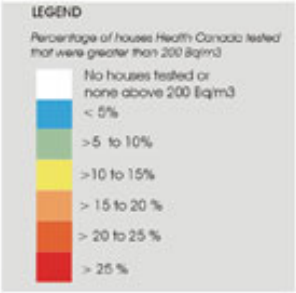
The regions of the country having higher radon levels (dark blue color) marked in green ovals are seen to have generally lower levels of lung cancer (dark blue or light blue) in the map on the right. The areas that have higher levels of lung cancer (dark red color) marked in red ovals are generally seen to correspond to lower levels of radon (light blue color) in the map on the left.

Radon levels in UK: http://archive.defra.gov.uk/evidence/statistics/environment/radioact/kf/rakf02.htm
UK Cancer Atlas: http://publications.cancerresearchuk.org/downloads/product/CS_CS_ATLAS_UK%26IRE.pdf

CANADA

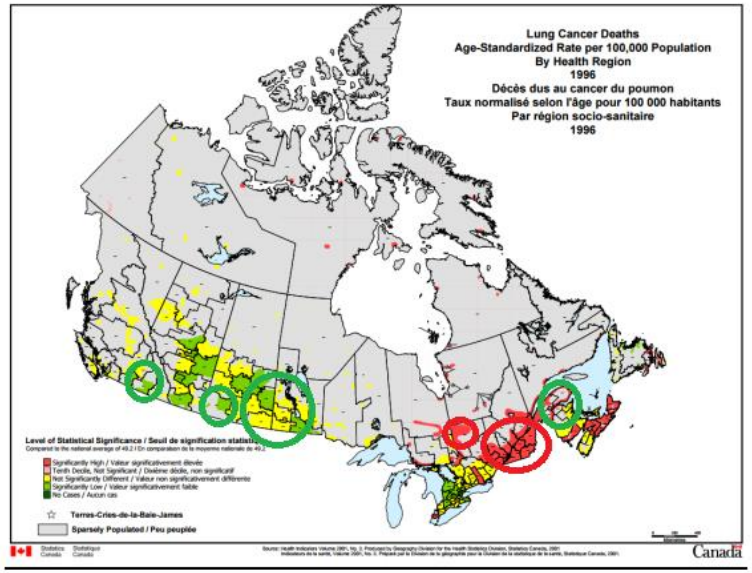
Radon Levels

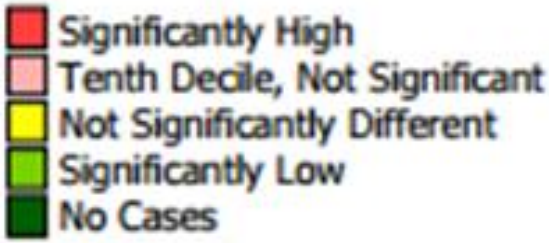




High Radon Levels mostly correspond to low or average lung cancer rates

Lung Cancer Mortality Rates



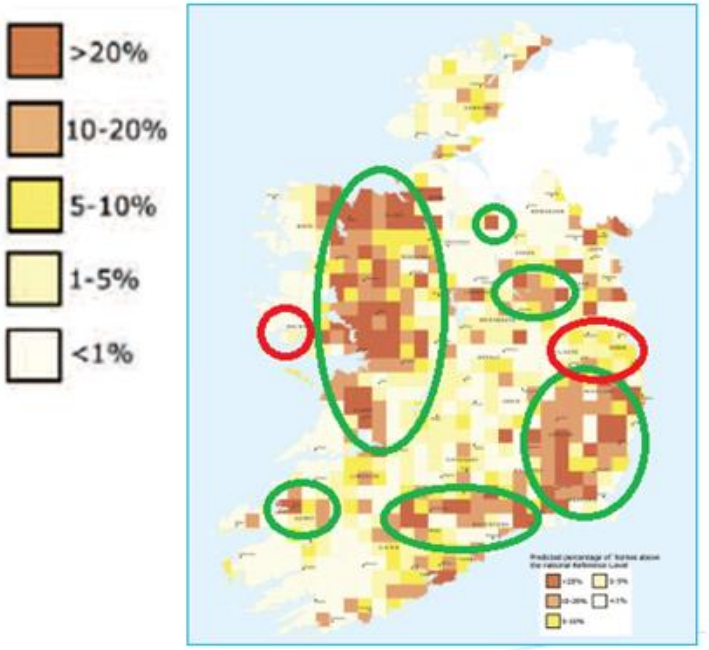


High lung cancer rates are in low or average radon areas

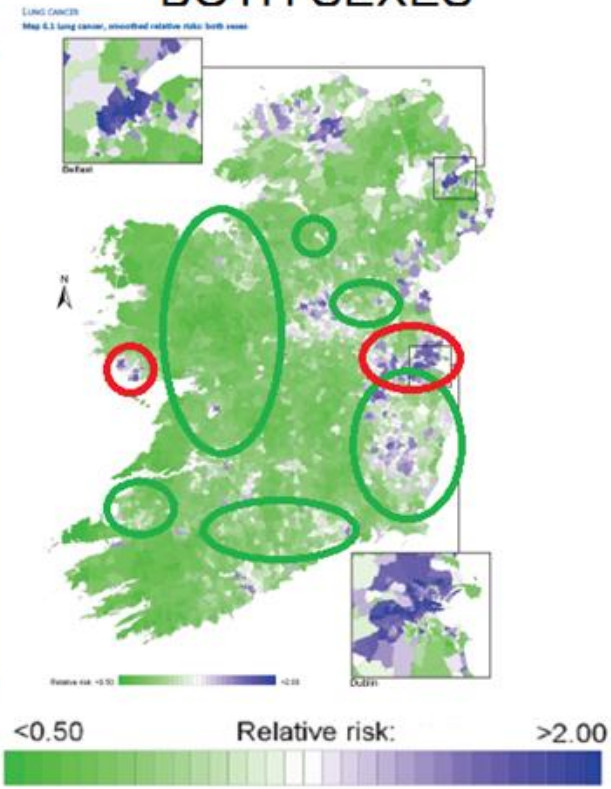
Radon map: http://www.terrapetratox.ca/wp-content/uploads/2014/06/Radon-in-homes-2014.jpg
Lung cancer map: http://www.statcan.gc.ca/pub/82-221-x/01002/pdf/4195955-eng.pdf

IRELAND

RADON LEVELS
%Homes above 100 Bq/m^3



LUNG CANCER RELATIVE RISK
BOTH SEXES



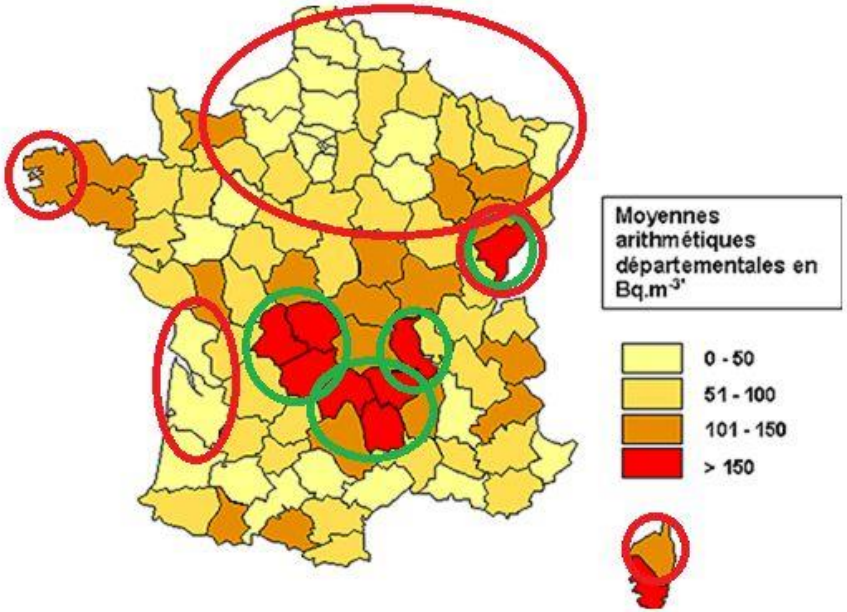
The regions of the country having higher radon levels (dark brown color) marked in green ovals are seen to have generally lower levels of lung cancer (green color) in the map on the right. The areas that have high levels of lung cancer (dark blue color) marked in red ovals are generally seen to correspond to lower levels of radon (white or yellow color) in the map on the left.

Radiation Doses Received by the Irish Population 2014
https://www.rpii.ie/pubs/reports/radiation/RPII_Radiation_Doses_Irish_Population_2014.pdf
All Ireland lung cancer atlas 1995-2007: http://www.ncri.ie/sites/ncri/files/atlas/2007/Lung%20cancer.pdf

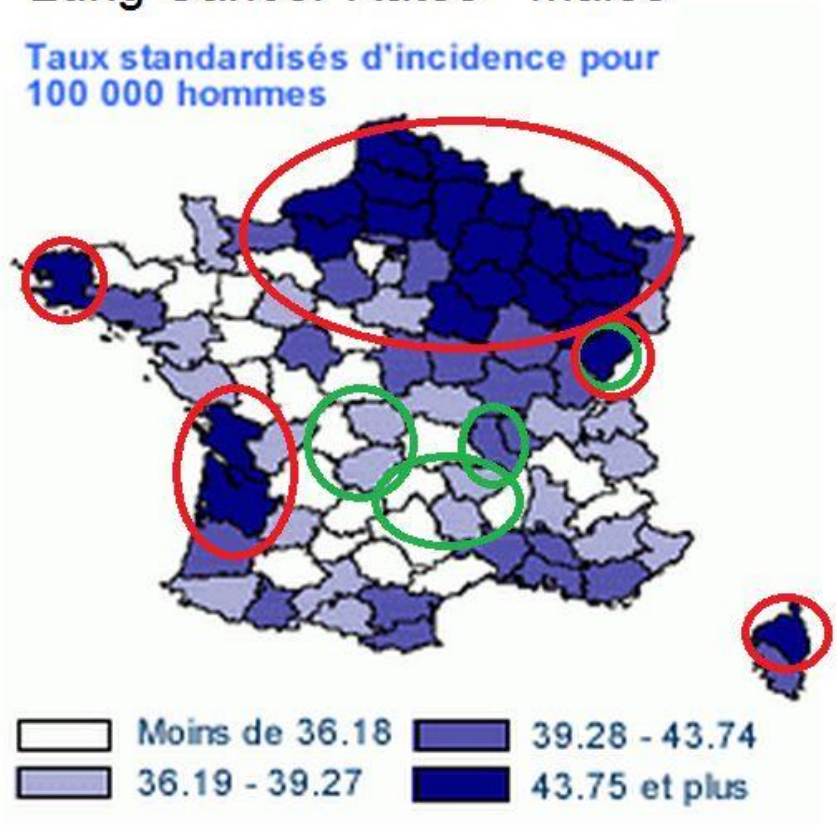
Radon Levels and Lung Cancer in France - Males

FRANCE

Radon Levels



Lung Cancer Rates - Males

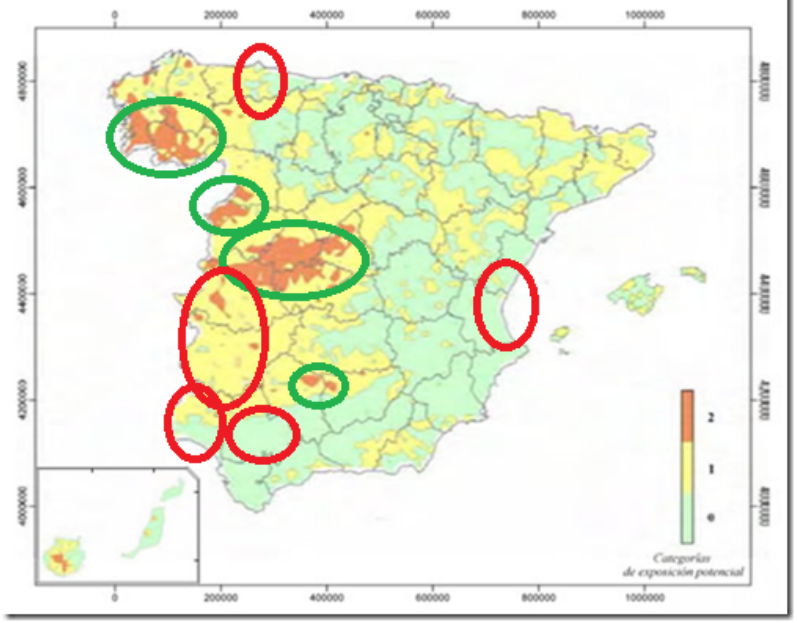


Radon Map of France:
http://www.irsn.fr/FR/connaissances/Environnement/expertises-radioactivite-naturelle/radon/Pages/4-Campagne-nationale-mesure-radon.aspx#.VLabddLF_To
France Lung Cancer map
http://www.doctissimo.fr/html/dossiers/cancer_poumon/sa_8065_cancer_poumon_femmes_explosion.htm

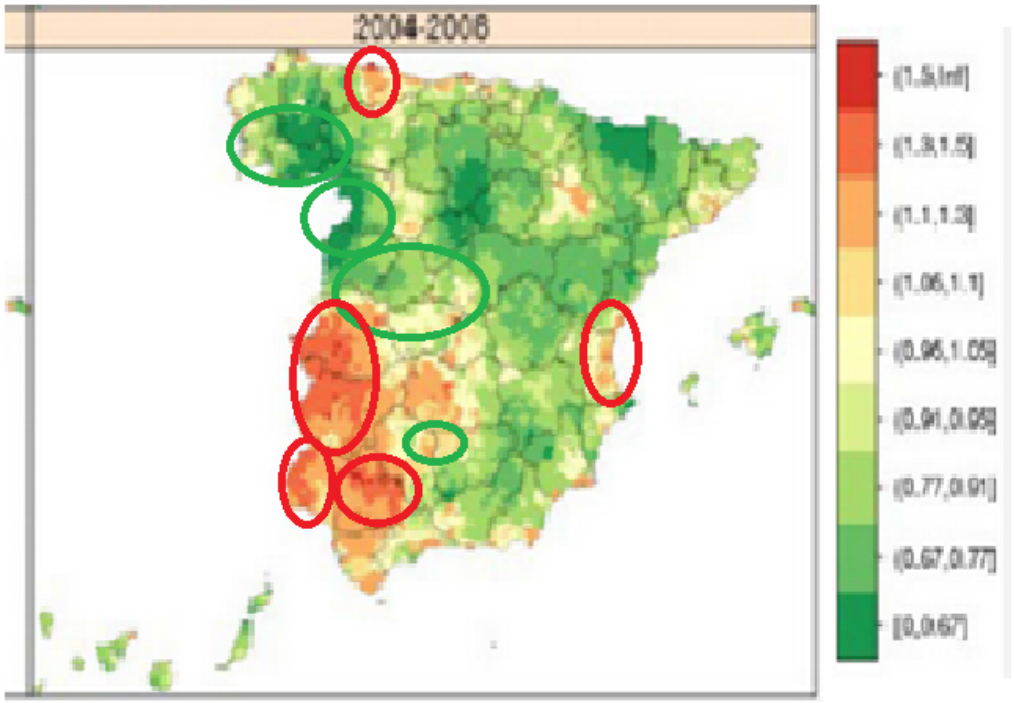
SPAIN

RADON LEVELS

Mapa predictivo de exposición al radón que divide el territorio en tres categorías de exposición potencial:baja(0), media (1) y alta (2), *CSN*



LUNG CANCERS - MALES



Distribución geográfica del cáncer de pulmón en España. Hombres

Radon Map

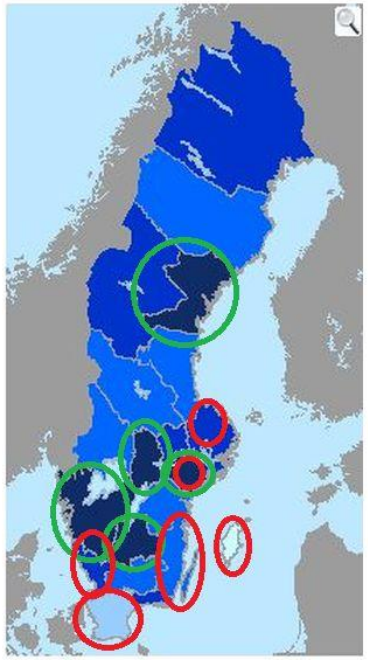
http://www.csn.es/images/stories/publicaciones/unitarias/informes_tecnicos/mapa_radn.pdf

Lung Cancer Map

http://oncologovalencia.com/mapa-de-distribucion-geografica-del-cancer-de-pulmon-en-espana/

SWEDEN

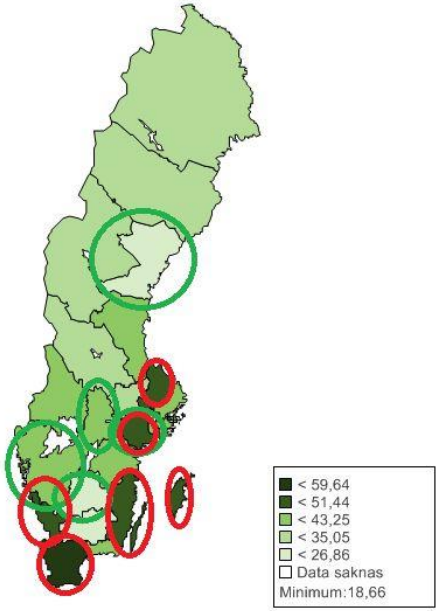
RADON



0-10%
10-20%
20-30%
30-40%
40%

Percentage of radon measured in single-family homes per county with radon concentrations above 200 and 400 becquerels per cubic meter of air, measurements performed until 1999.

LUNG CANCER



Nya cancerfall. Åldersstandardiserad incidens per 100 000 enligt befolkningen 2000, Ålder: 0-85+, Män, Diagnos:162 Lunga, luftstrupe och bronker, 163 Lungcancer, ospecificerad, oavsett tumörtyp, 2013

Radon map
http://www.miljomal.se/Miljomalen/Alla-indikatorer/Indikatorsida/?iid=109&pl=1
Cancer Map
www.socialstyrelsen.se/statistik/statistikdatabas/cancer

Summary of Comparison of Radon and Lung Cancer Maps

- It is remarkable how High Residential Radon Levels correspond mostly to low or average lung cancer rates in all the countries
- High lung cancer rates are mostly in low or average radon areas
- Confounding by Smoking cannot explain the observed negative correlation between radon levels and lung cancers in the USA
- Considering the consistency of the observation in different countries, it would be incredible to claim that confounding by smoking can explain the observed negative association between residential radon levels and lung cancers.

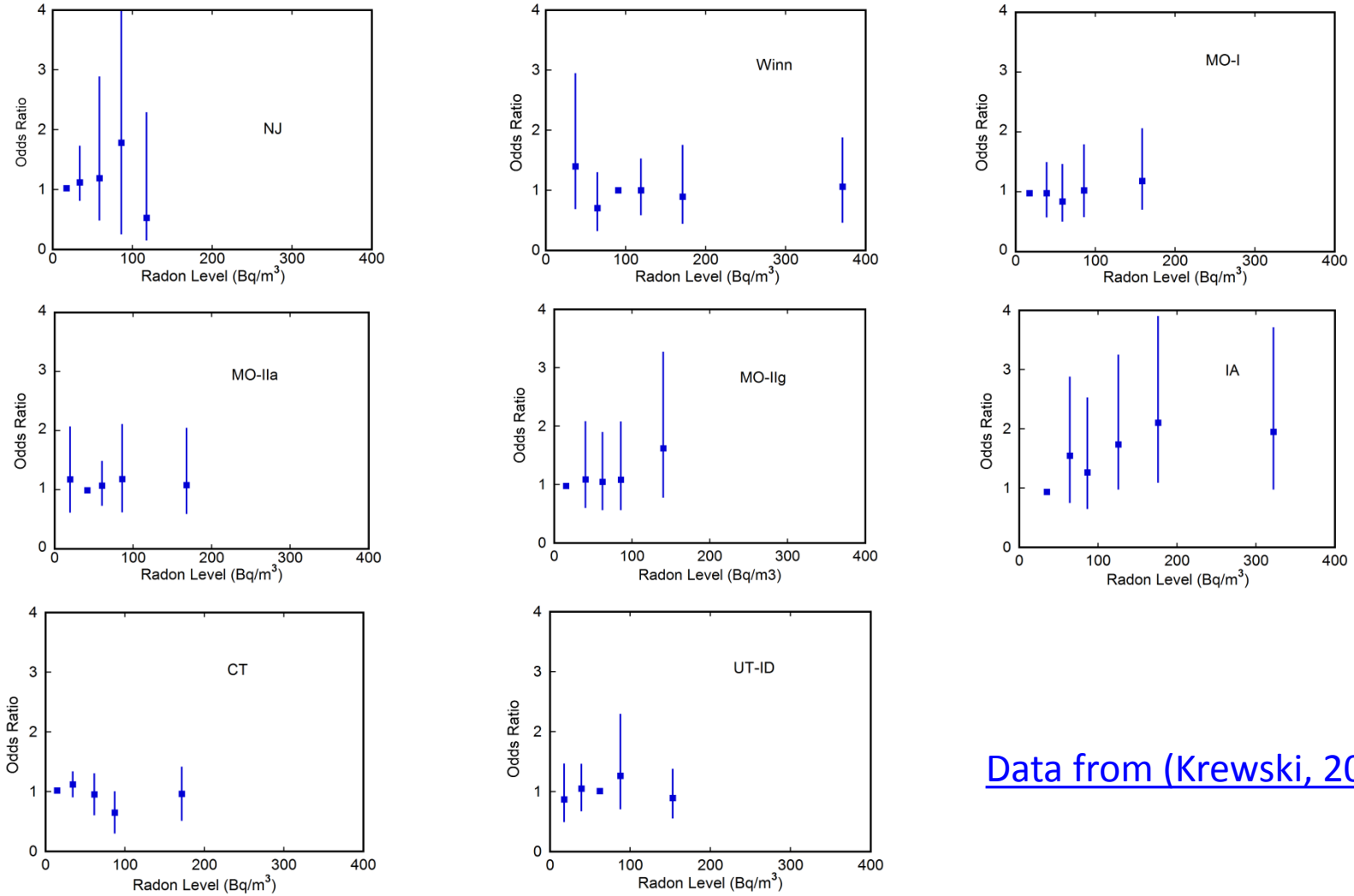
We cannot conclude from these negative correlations alone that higher radon levels reduce lung cancers. Correlation does not necessarily suggest causation.

However, it is likely that confounding factors cannot explain the observed negative correlation, considering that it is observed in all the countries examined.

Therefore, the hypothesis that higher radon levels reduce lung cancers should be seriously entertained.

Discussion of Some Case Control Studies

A combined analysis of North American case-control studies of residential radon and lung cancer

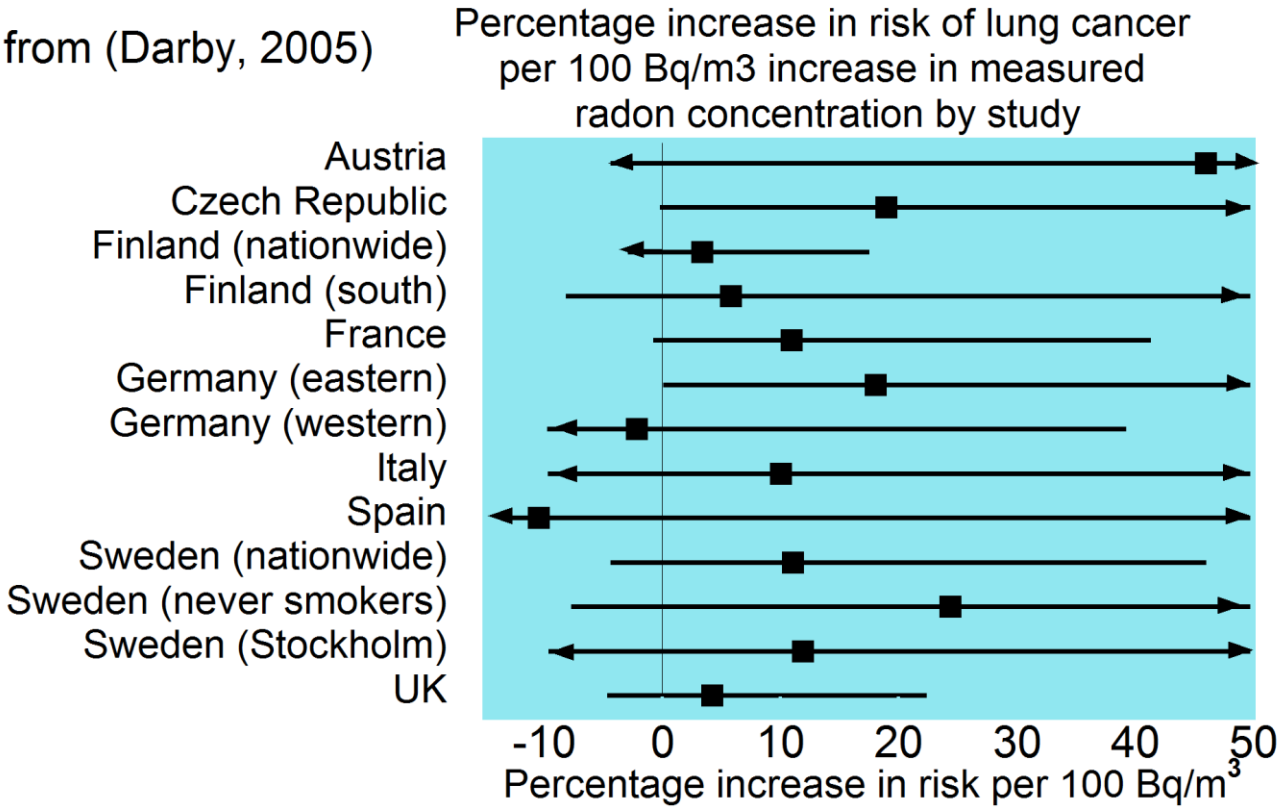


Data from (Krewski, 2006)

Odds Ratio and 95% CIs for Lung Cancer as a function of radon level. Insufficient statistics to make any reliable conclusion on the shape of dose-response, even after pooling the studies.

Radon in homes and risk of lung cancer: collaborative analysis of individual data from 13 European case-control studies

Data from (Darby, 2005)



(Darby, 2005)

All the data are consistent with no increased risk of lung cancers with increased radon levels.

Epidemiological Evidence for Possible Radiation Hormesis from Radon Exposure: A Case-Control Study Conducted in Worcester, MA

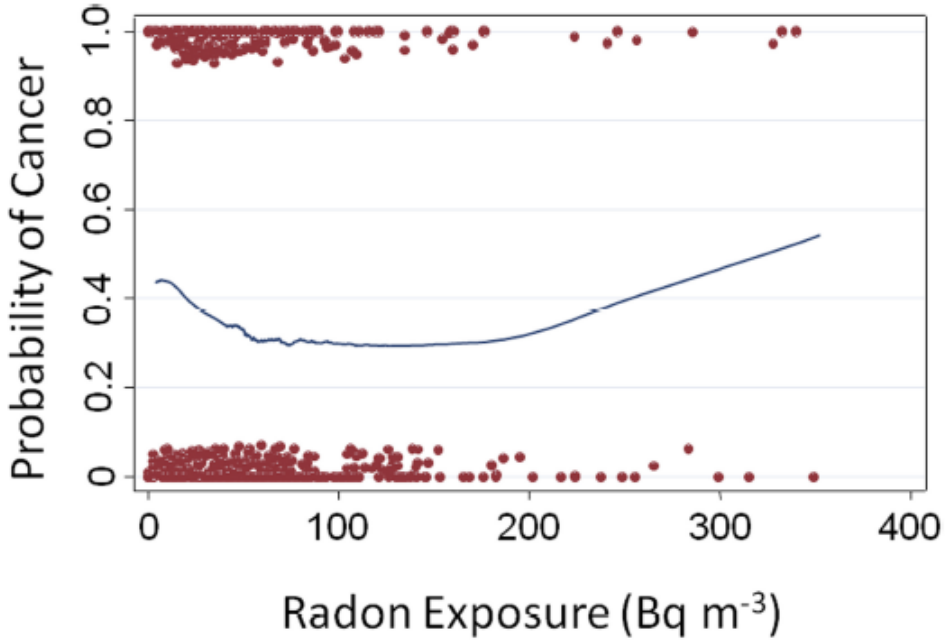
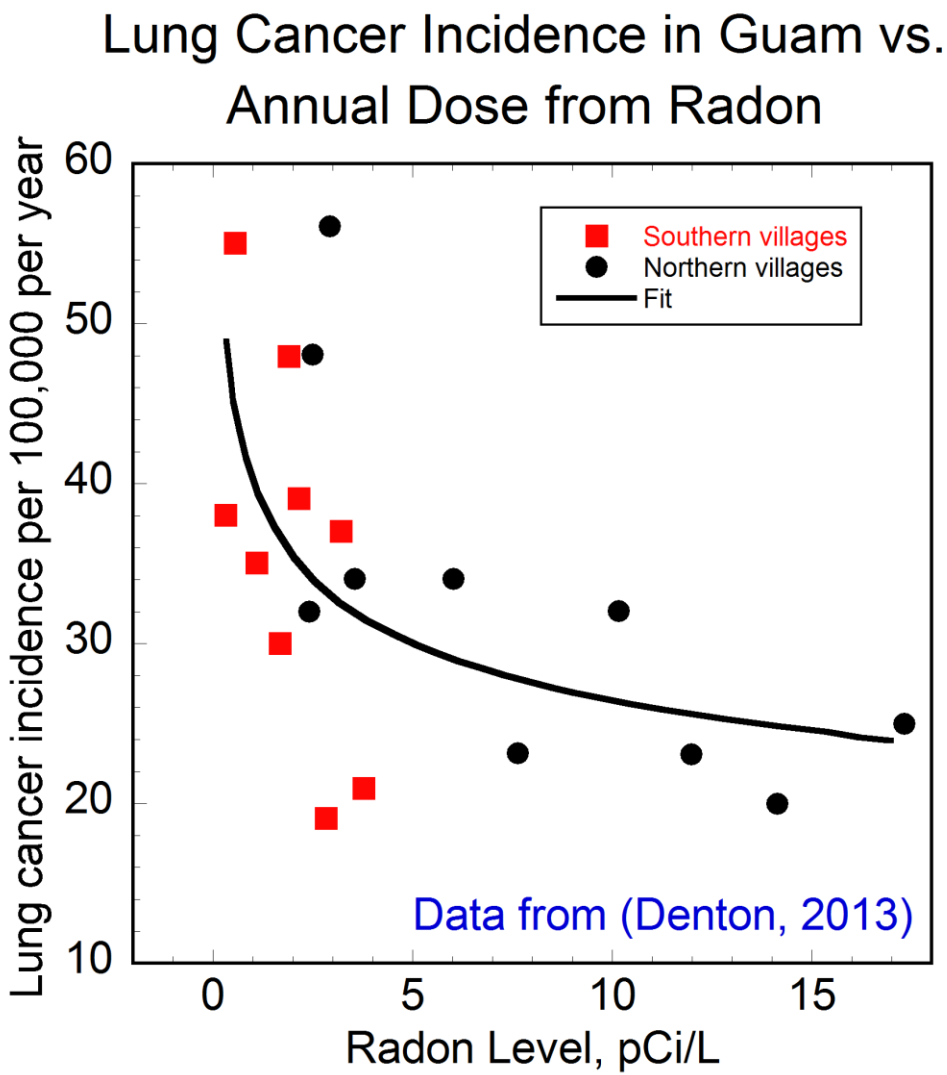


FIGURE 1: Lowess smoothing average of cases and controls. Points near the top of the plot represent cases while those at the bottom represent the controls. These points have been jittered to better show the distribution of cases and controls as a function of radon exposure.

Figure from: Thompson, R. E. 2011. Epidemiological Evidence for Possible Radiation Hormesis from Radon Exposure: A Case-Control Study Conducted in Worcester, MA. *Dose Response,* 9**,** 59-75. DOI: 10.2203/dose-response.10-026.Thompson
http://journals.sagepub.com/doi/full/10.2203/dose-response.10-026.Thompson

The data are consistent with hormetic reduction of lung cancers in the 100-200 Bq/m^3 range.



Data are consistent with hormetic reduction of lung cancers at higher radon levels. The results are strongly suggestive that indoor radon levels lower the risk of lung cancer.

Overall Conclusion

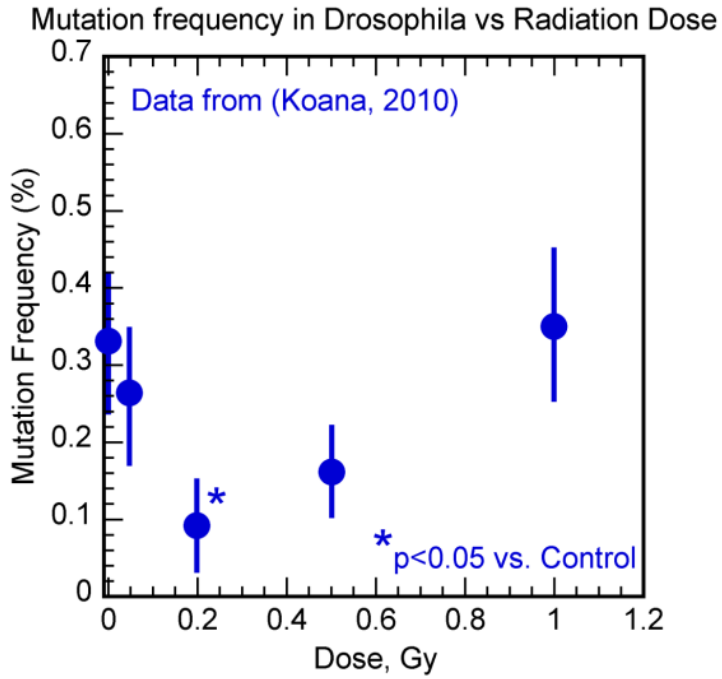
There is no reliable evidence for the increase in lung cancer risk from residential radon, but there is considerable evidence for reduction of lung cancers correlated with higher residential radon levels.

However, current prevailing view is that cancer risk increases with radiation dose based on the LNT model. Is the LNT model justified?

Usually Proposed Justification for the LNT Model

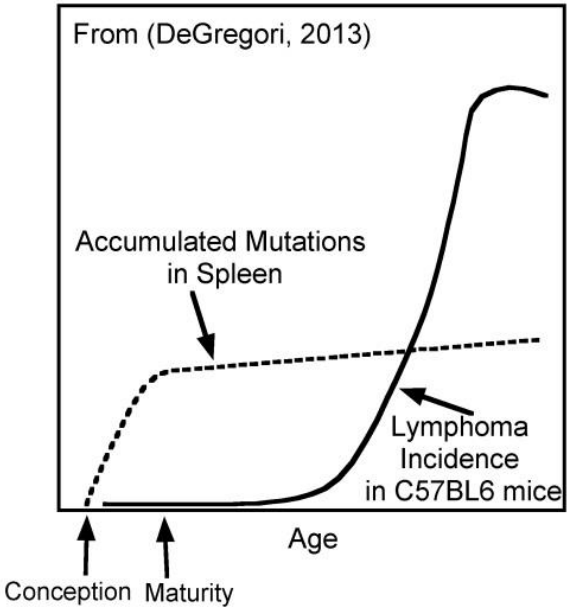
The LNT Model is justified based on the ideas

- Slight increase in radiation dose increases DNA damage and mutations
- Slight increase in mutations increases cancers



For low radiation doses, mutations do not increase with radiation dose but rather decrease

Accumulated Mutations and Lymphoma Incidence in Mice vs. Age



Cancers do not increase with mutations

Thus, there is no valid justification for the LNT Model

Examples of Evidence Against the LNT Model

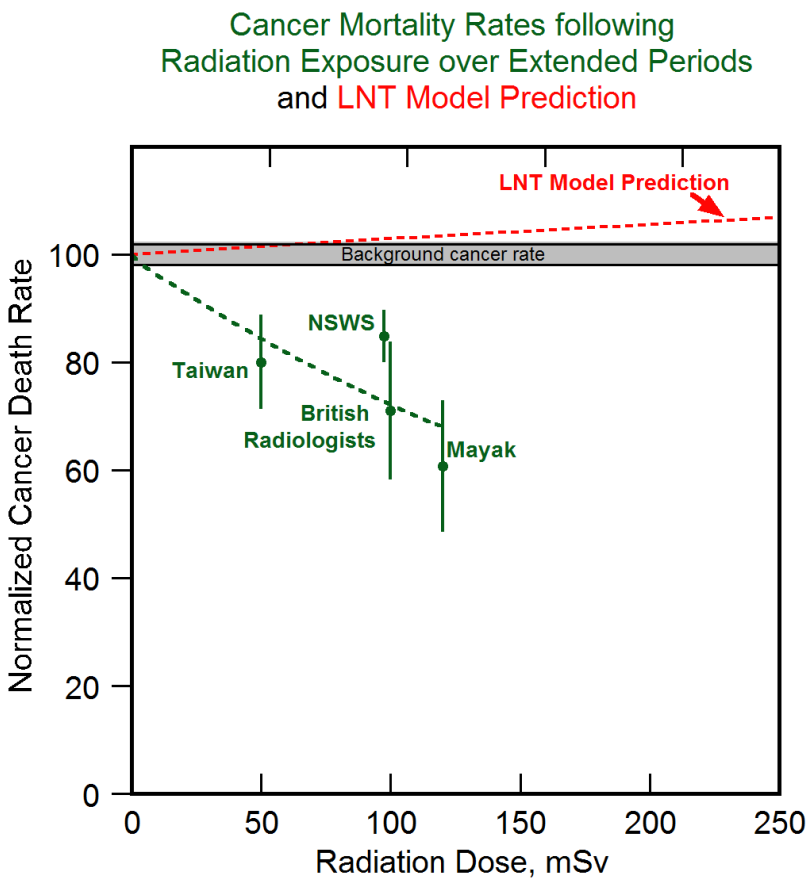


Figure legend:

LNT model Prediction – Using BEIR VII Report (NRC, 2006)

Taiwan - Residents of radio-contaminated apartments in Taiwan (Hwang, 2006)

NSWS - Radiation workers in Nuclear Shipyard Worker Study (Sponsler, 2005)

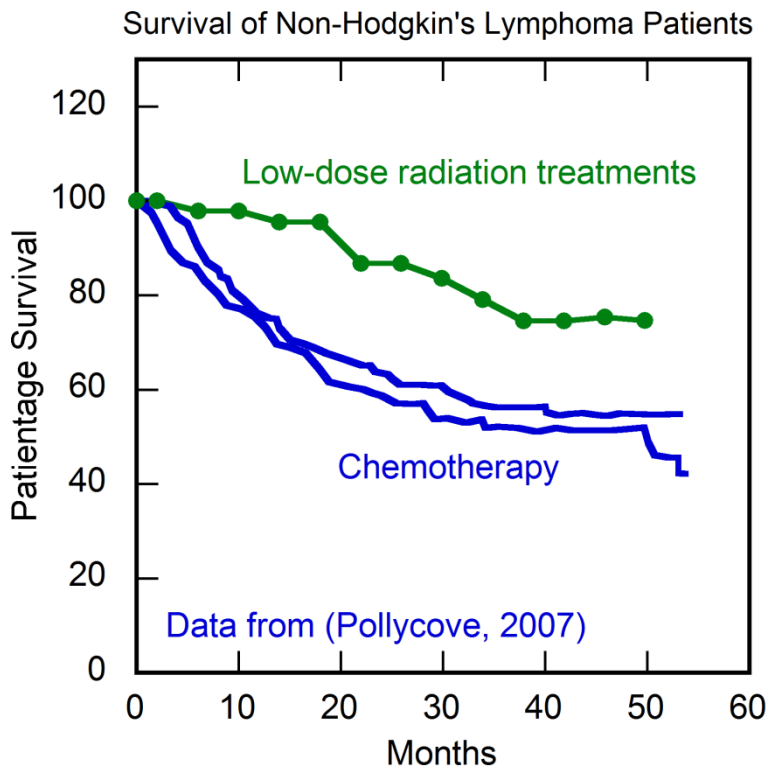
British Radiologists - British Radiologists who entered service during the period 1955-1979 (Berrington, 2001)

Mayak - Evacuated residents of villages near Mayak Nulcear Weapons Facility (Kostyuchenko, 1994)

There are many faulty publications that claim support for the LNT model or low-dose radiation carcinogenicity. Such publications should not be used.

Low-dose radiation exposures have resulted in reducing cancers contradicting the LNT model prediction and consistent with radiation hormesis, the concept that low levels of radiation reduce cancers.

Effect of Repeated Low-dose radiation Treatments vs. Chemotherapy on Cancer Patient Survival



Repeated low-dose radiation treatments resulted in better cancer patient survival compared to chemotherapy. Low-dose radiation had a cancer therapeutic effect, contradicting the LNT model prediction of more cancers and consistent with radiation hormesis.

What are the most important data for evaluating the health effects of low-dose radiation?

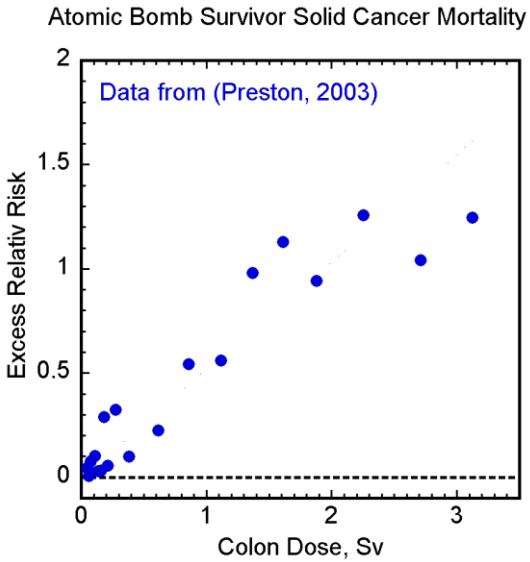
BEIR VII Report says on p.141:

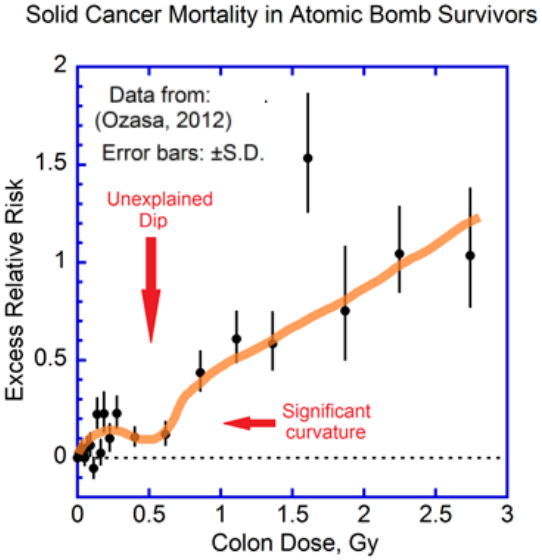
> Because of its many advantages, the LSS cohort of A-bomb survivors serves as the single most important source of data for evaluating risks of low-linear energy transfer radiation at low and moderate doses. This chapter describes

(Hall & Brenner, 2008) say in "Cancer risks from diagnostic radiology"

> Data from atomic bomb survivors represent the "gold standard" in the quantitative assessment of radiation carcinogenesis risks at low doses. There are several

Shape of Dose-Response in the Atomic Bomb Survivor Cancer Mortality Data





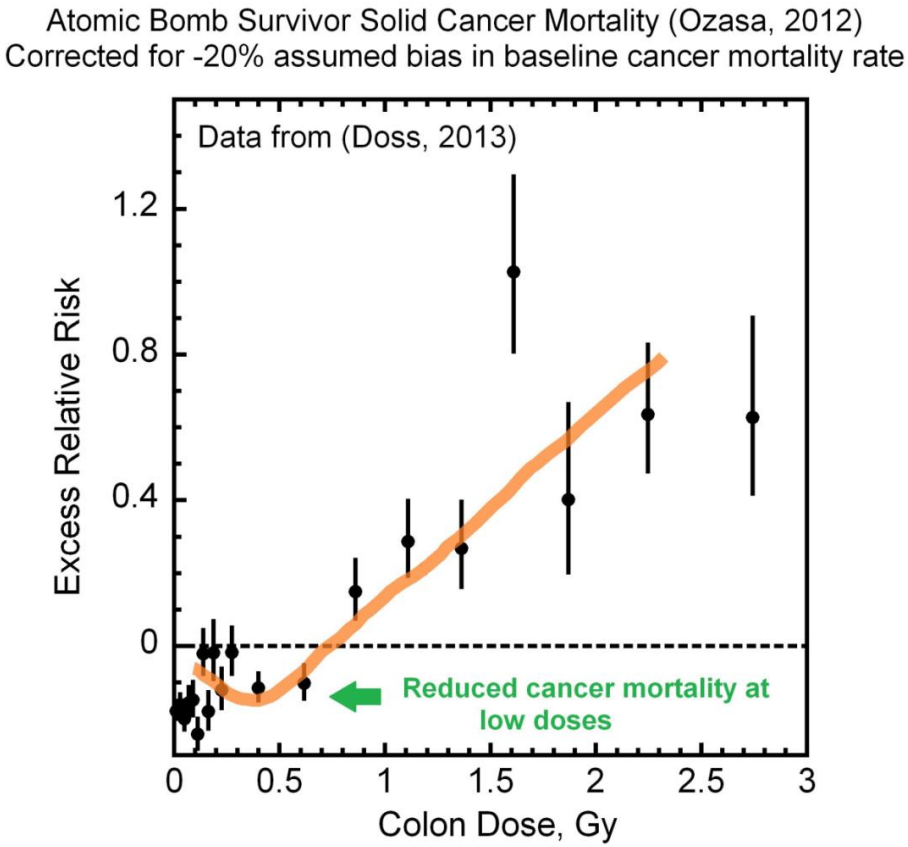
In (Ozasa, 2012), Excess Relative Risk rises with dose from 0 to 0.25 Gy, decreases with dose from 0.25 to 0.5 Gy , and then rises with dose, resulting in a significant curvature. LNT model cannot explain the reduction of cancer risk for doses near 0.5 Gy.

Ozasa et al. state:

"The curvature over the 0-2 Gy range has become stronger over time, ……., and has become significant with longer observation"

The significant curvature in the dose-response of the atomic bomb survivor cancer mortality data is inconsistent with the LNT model.

Atomic Bomb Survivor Data Corrected for Bias in Baseline Cancer Rate



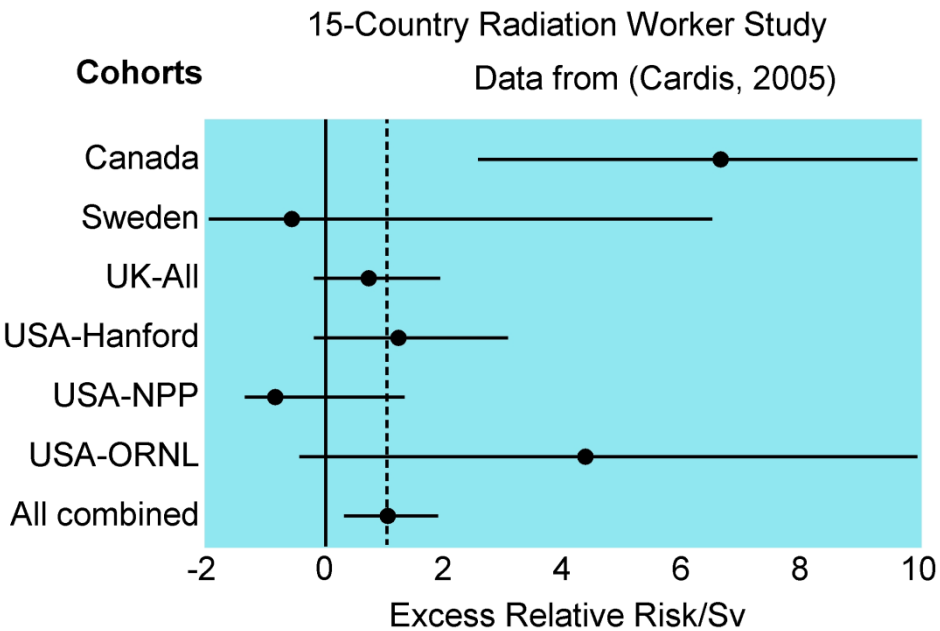
Correcting for the likely negative bias in the baseline cancer rate results in a J-shaped dose-response curve consistent with radiation hormesis. (Doss, 2012), (Doss, 2013)

The most important data for determining health effects of radiation, the atomic bomb survivor data, are inconsistent with the LNT model but are consistent with radiation hormesis.

Discussion of a few evidences claiming to support the LNT Model

15-Country Study of Radiation Workers

(Cardis, 2005)



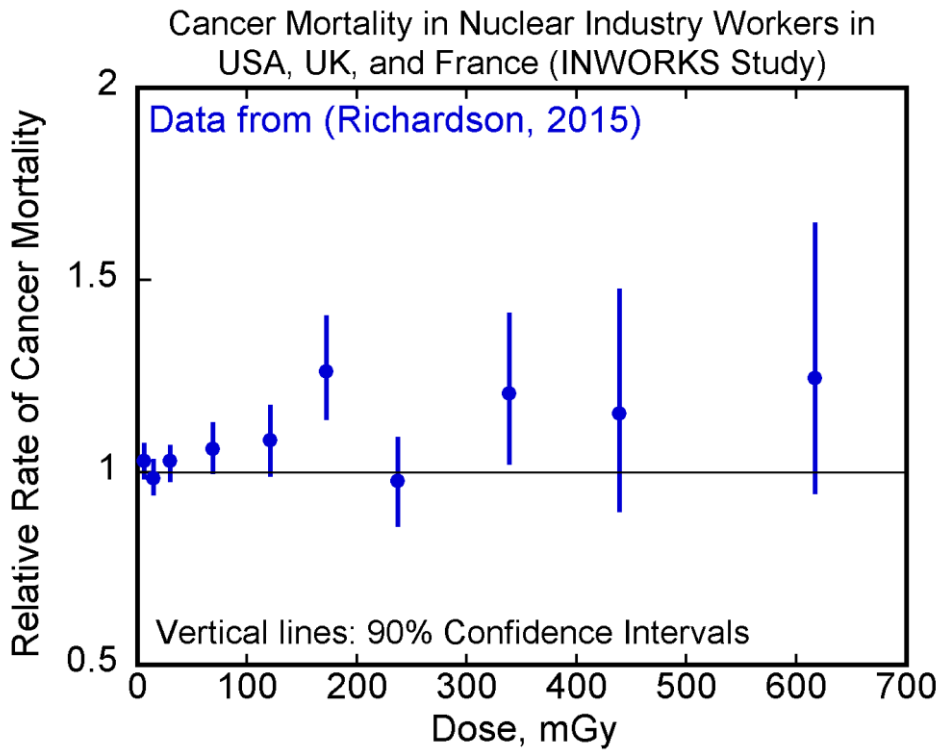
Canadian data are clearly inconsistent with most other data.

BEIR VII Report , instead of asking for a re-examination of the Canadian data, utilized these results to support the LNT model in an Addendum to the Report which was already finalized.

In 2011, CNSC withdrew Canadian data because of faults identified in them, negating the conclusion of the 15-Country Study.

BEIR VII report used poor judgment in accepting this study at face value.

Example of Recent Evidence for the LNT Model



Poor design of study – Ignored much larger medical radiation doses in later years of the study.

Poor quality data – With such large error bars, cannot draw any reliable conclusions from the study.

FINAL CONCLUSION REGARDING RADON

Based on all the evidence presented above, it is clear that higher levels of residential radon reduce lung cancers and so radon mitigation in such homes would be increasing the risk of lung cancer.

The claims of EPA that residential radon causes lung cancers based on the LNT model cannot be accepted since there is no valid evidence for the LNT model but there is evidence for radiation hormesis.

Organizations which Claim that Residential Radon Causes Lung Cancer and Recommend Radon Mitigation

Advisory Bodies

•IAEA, WHO, National Academy of Sciences, NCRP

Government Agencies

•EPA, CDC, Health Canada, US Surgeon General, Agency for Toxic Substances and Disease Registry, National Toxicology Program, EPA (Ireland), Many State Agencies

Professional Organizations

•American Cancer Society, American Lung Association, Cancer Research UK, Canadian Cancer Society, Ontario College of Family Physicians, Penn Medicine, Citizens for Radioactive Radon Reduction, National Cancer Institute

Websites

•Mercola, SOSRadon, WebMD, HealthDay,

The actions recommended by these entities (radon mitigation in homes with higher radon levels) would increase lung cancer risk. Such misinformation by these influential entities has prevented the study and use of higher levels of residential radon for reducing lung cancers in spite of the vast available evidence.

Summary

- Radon-Lung cancer data in many countries are indicative of the cancer preventive effect of low-dose radiation known as radiation hormesis.
- Many other data are consistent with radiation hormesis.
- LNT model supporting publications have major flaws.
- Prospective studies are needed to verify the reduction of lung cancers at higher radon levels, so that, if verified, radon can be used to reduce lung cancers.
- Radon mitigation recommended by EPA may be increasing lung cancer risk.

Please share this document widely with your contacts through email, social media platforms, etc. so that more people are aware of the observed beneficial health effects of radon. Please also visit the XLNT Foundation website and support its work. Thanks.