Radon Facts Summary

Radon-222 (physical half-life 3.8 days) arises as a radioactive decay product of radium-226 (Ra-226), which is widely dispersed in rocks and soil. Rn-222 migrates from rocks and soil into homes where it accumulates in confined spaces (e.g., basements). Radon progeny (i.e., radon radioactive decay byproducts) emit both *highly ionizing alpha particles* and *sparsely ionizing gamma rays*. Almost all measurements of radon levels in the home or outdoors are expressed as the concentration of radon in units of picocuries per liter of air (pCi/liter), or in SI units as Becquerels per cubic meter (Bq/m^3).

The air we breathe contains both radon gas and the solid byproducts from radioactive decay of radon that get attached to aerosol particles (aerosol particles are easily deposited both indoors and outdoors). Radon and its radioactive decay byproducts will follow the air into the lungs when breathing. Radon itself will mostly follow the air out again. Consequently, it is the radioactive decay byproducts which remain in the lungs that produce the radiation dose to lung tissue.

Several attempts have been made to calculate the energy deposited in the lungs from radon decay byproducts. These calculations are not easy since several important factors are unknown. In addition, the half-lives for the byproducts are very short and the radiation dose is received in a short period of time.

A large number of epidemiological studies on radon in homes and lung cancer have been published during the last 30 years. Lung cancer is by far the leading cause of cancer death among both men and women, and the main cause is smoking. Other causes are asbestos, diesel fumes, radiation and nature itself.

The <u>average</u> background radiation dose (cosmic, terrestrial, radon, and internal sources) for people living in America is generally taken to be ~310 mrem/year, with the radon contribution to this dose being ~200 mrem/year (NCRP[a], US NRC[b], US EPA[c]). (The rem is a dose unit derived to provide a common reference for the biological effects due to different forms of ionizing radiation; mrem = 0.001 rem.) Note that people living at higher elevations (e.g., Albuquerque or Denver) will receive higher annual background doses from cosmic radiation than people living at lower elevations. Radiation doses from terrestrial sources and radon in America will also vary with location.

According to a report by the United Nations Scientific Committee on the Effects of Atomic Radiation[d] (UNSCEAR) people living in a high radon concentration of 1000 Bq/m^3 receive a dose of 80 mSv/year (8000 mrem/year). The UNSCEAR report also specifies the population-weighted *global average* radon concentration as 40 Bq/m^3 indoors and 10 Bq/m^3 outdoors. (Using a dose of 8000 mrem/year for a radon concentration of 1000 Bq/m^3 produces *global average* indoor and outdoor radon doses of 320 mrem/year and 80 mrem/year, respectively. If it is assumed that the UNSCEAR *global average* indoor and outdoor concentrations apply in America and 50% of an American's time is spent indoors and 50% outdoors, then the annual average radon dose would be 200 mrem.)

According to the United States Environmental Protection Agency (US EPA), a "typical" indoor radon concentration in American homes is 2.7 pCi/liter (~100 Bq/m^3), while the average outdoor radon concentration in America is 0.4 pCi/liter (~15 Bq/m^3). With a 50% indoor/outdoor assumption, these radon concentrations would result in an annual radon dose of ~460 mrem, which is 2.3 times the NCRP annual average radon dose of 200 mrem for Americans. (Note that the 200 mrem annual average radon dose for Americans equates to an average indoor radon concentration of ~1 pCi/liter.)

Further, the US EPA has recommended an indoor radon concentration of 4 pCi/liter (148 Bq/m^3) as the action level for implementing measures to decrease radon in American homes (see map below for predicted fraction of American homes exceeding 4 pCi/liter). Note that the NCRP recommended action level is 8pCi/l.[e] The practical implication of this action level is that a radon concentration ≥ 4 pCi/liter generally requires remediation to reduce the concentration below 4 pCi/liter in order to sell one's home. Assuming 50% of an American homeowner's time spent indoors, 4 pCi/liter would result in a radon dose of ~653 mrem/year.

Regardless of the actual radon concentrations and associated radiation doses in American homes, any concern about the potential health effects of indoor radon should be based on actual observed effects (see graph below of normalized lung cancer mortality vs. mean radon level). In this regard, there are some locations in the world where environmental radon doses are much higher, by more than an order of magnitude, than any found in American homes. For example, because of very high radon gas concentrations, average background doses in Guarapari, Brazil and Ramsar, Iran can be as high as 17,500 mrem/year and 26,000 mrem/year, respectively. Yet there is no evidence of increased cancers among the people living in these areas compared to people receiving much lower background doses.

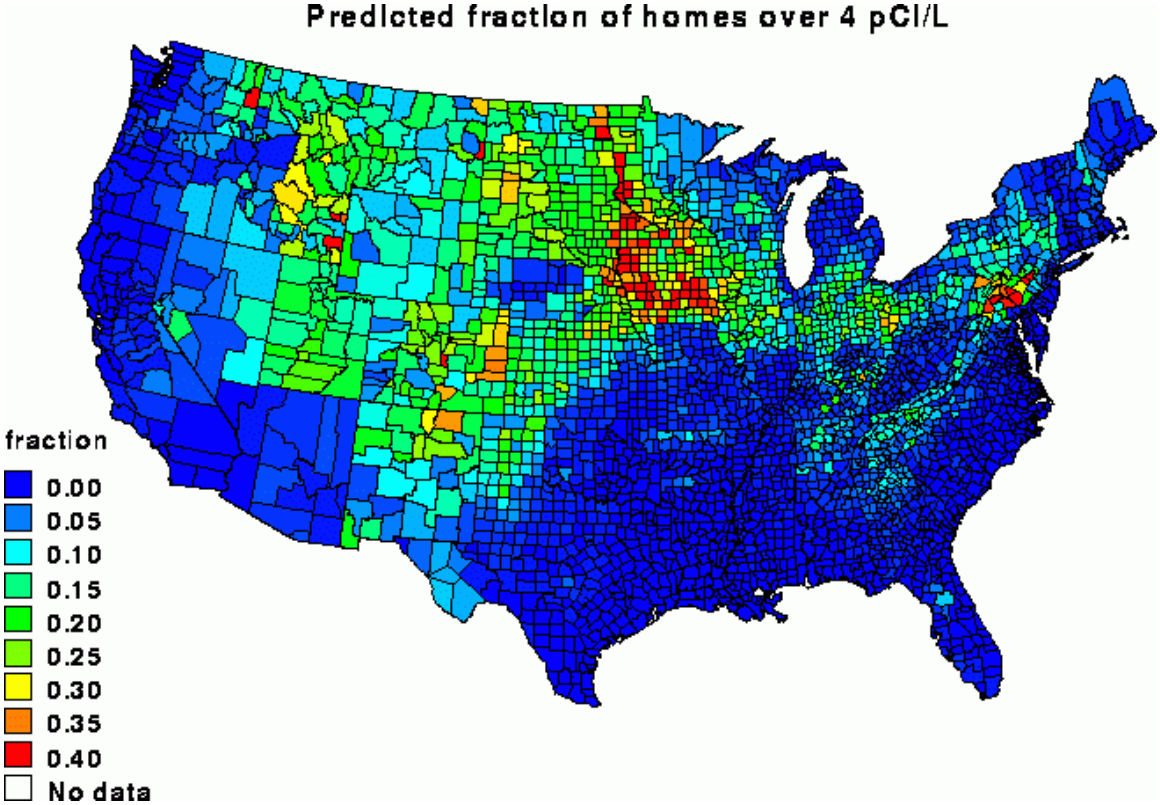
Furthermore, no compelling evidence for increased lung cancer risk has yet been demonstrated from radon exposure levels of 4-8 pCi/liter.[e]

And as a final note, a report by the International Commission on Radiological Protection[f] (ICRP) concludes there is general agreement that epidemiological methods used for the *estimation* of cancer risk do not have the power to directly reveal cancer risks for doses up to approximately 100 mSv (10,000 mrem). That is, there is no evidence to support cancer risk estimates.

Notes:

a. National Council on Radiation Protection and Measurements; NCRP No. 160, 2009
b. United States Nuclear Regulatory Commission
c. United States Environmental Protection Agency
d. United Nations Scientific Committee on the Effects of Atomic Radiation: UNSCEAR 2000 Report

e. Journal of Nuclear Medicine, Vol. 35, No. 2; Feb. 1994
f. International Commission on Radiological Protection; ICRP Report 103 (2007)

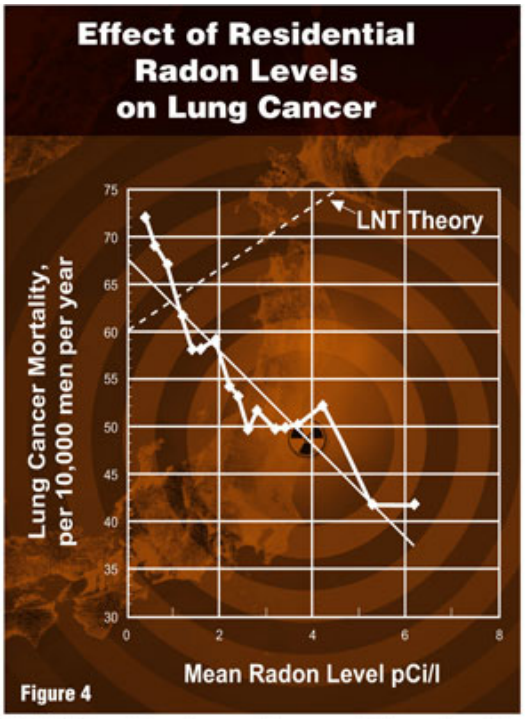


Indoor Radon values (UNSCEAR 2000 and 2006)

In Kinsarvik in the western part of Norway the highest radon values have been measured – both inside the houses as well as for the outside air.
Values above 50 000 Bq/m³ inside and up to 287 Bq/m³ outside (1 meter above the ground) have been measured .

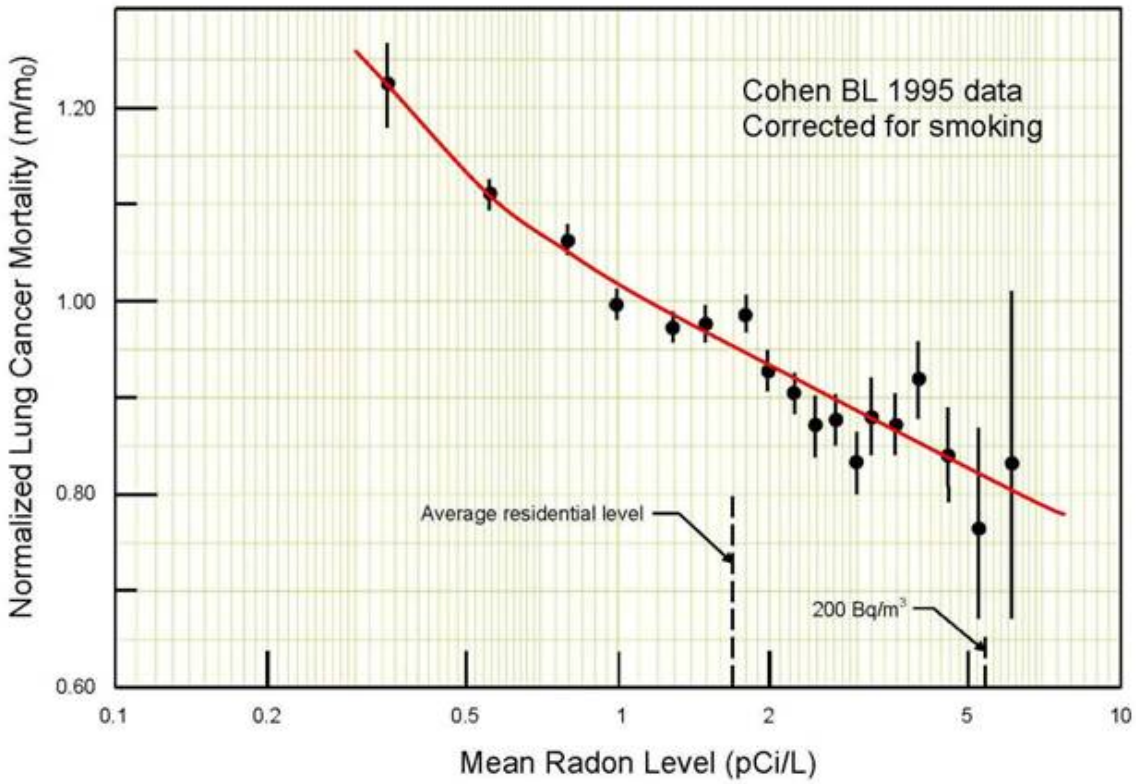
Country	Average Bq/m³	Maximum Bq/m³
United States	46	
Canada	28	1720
China	46	
India	57	210
Iran	82	3070
Denmark	59	1200
Finland	120	20 000
Norway	**73**	**50 000**
Sweden	108	85 000
France	62	4690
Germany	50	10 000
United Kingdom	20	17 000
Australia	11	420

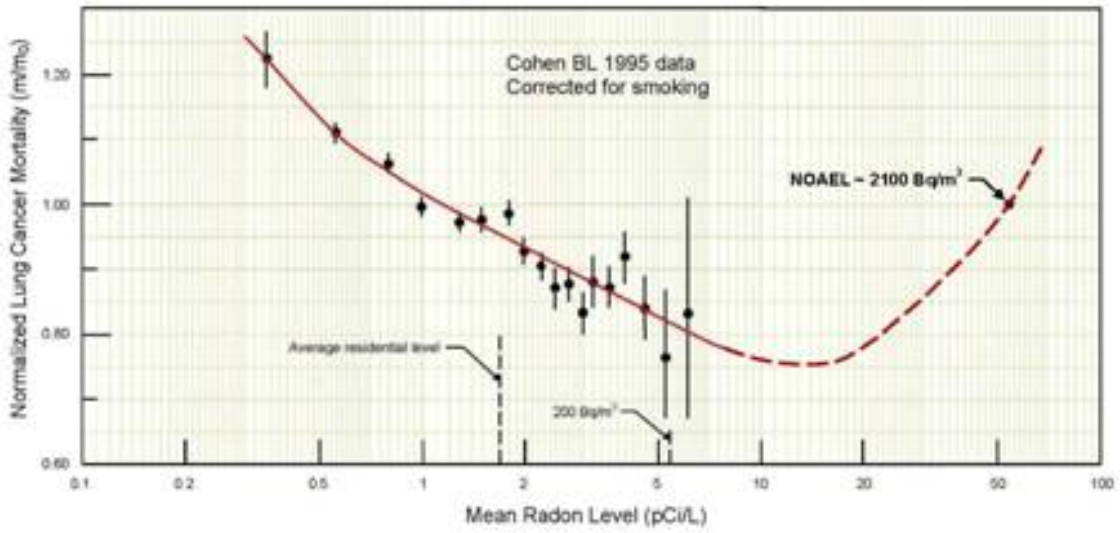
Professor Bernie Cohen's initial five-year investigation of radon-induced lung cancer covered 1,729 counties, comprising about 90 percent of the United States. It considered radon data from the EPA and state agencies, and 272,000 measurements by Pitt researchers. The research found that instead of increased cancer with the increased presence of radon, the cancer rate decreased significantly as noted in Figure 4.



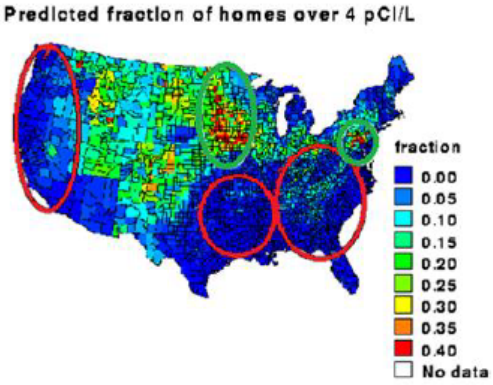
While LNT predicts an increase in cancer with increasing radon exposure, Cohen's study of 90 percent of the U.S. population shows a decrease. (Each data point represents 89 counties.)

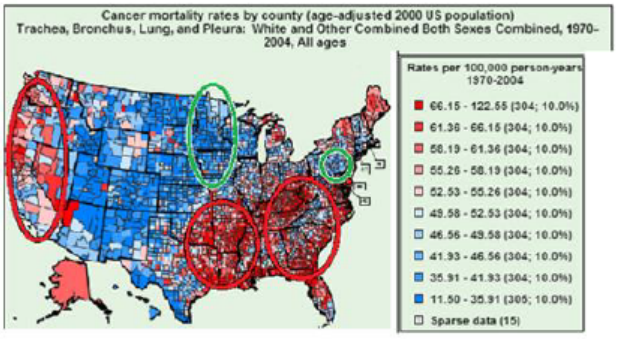
Dr. Cohen's study showed that between zero and six pCi/l — a normal range for U.S. residences — cancer rates decreased for men and women, both smokers and non-smokers. This was in direct contradiction to the EPA prediction using LNT. The difference is put forth by Cohen and his supporters as "our discrepancy," with the challenge that unless "our discrepancy is resolved, the LNT is in error." No other researcher has yet mounted a credible challenge.


Cohen BL 1995 data
Corrected for smoking
Average residential level
200 Bq/m3
Normalized Lung Cancer Mortality (m/m0)
Mean Radon Level (pCi/L)
1.20
1.00
0.80
0.60
0.1
0.2
0.5
1
2
5
10


Cohen BL 1995 data
Corrected for smoking
NOAEL ~ 2100 Bq/m3
Average residential level
200 Bq/m3
Normalized Lung Cancer Mortality (m/m0)
Mean Radon Level (pCi/L)
1.20
1.00
0.80
0.60
0.1
0.2
0.5
1
2
5
10
20
50
100

Radon Levels and Lung Cancer in USA





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

Green ovals enclose high radon level areas; Red ovals enclose areas having high lung cancer rates. There is little overlap between red ovals and green ovals.

44

EPA's claim that radon kills 90,000 people a year is patently false. EPA recommends radon remediation if radioactivity exceeds 0.148 Bq per liter of air. [One Bq is one atomic disintegration.]
http://www.theenergycollective.com/…/residential-radon-safe…

New analysis of 34 radon health effects studies concludes lung cancer risk is independent of radon below 0.838 Bq per liter. The paper also invalidates LNT and provides evidence that low doses can have positive health effects.
https://academic.oup.com/…/…/doi/10.1093/jrr/rrx061/4654992…

Maps of radon and lung cancer have been compared for many other regions

Similar pattern – highest radon level areas having lower lung cancer rates, and highest lung cancer rates corresponding to lower radon levels - is observed for different states of the USA, for different countries in Europe, etc. See the unpublished report.

Smoking is an important confounder for lung cancers. However, it is highly unlikely that smoking prevalence would always be correlated with radon levels to explain the observed correlation in so many different regions around the world. Therefore, the effect we have observed is likely a real effect, and is consistent with other observations of reduced cancers from low-dose radiation exposures.

46