LUNG CANCER PREVENTION THROUGH RADON MITIGATION: URGENCY AND EFFECTIVENESS FROM A LOCAL PERSPECTIVE

L. Moorman, Ph.D.
Radon Home Measurement and Mitigation, Inc.
Fort Collins, Colorado
USA

ABSTRACT

A realistic estimate, incorporating radon concentration distributions, is given of the total number of local lung cancer incidences attributable to radiation from radon and its decay products in the residential environment in a community with an increased average indoor-air radon concentration. An estimate of the currently prevented lung cancer incidences due to past mitigations is presented. Finally we present the expected residual lung cancer death rates due to radon exposure for this community during the next decade. The purpose of this presentation is to provide information to educators and mitigators in order to aid in the process for legislative action and to demonstrate the effectiveness of small to medium sized companies. Finally, the presented information could serve as an example in the broader national discussion.

MOTIVATION AND GOAL

There is a need for realistic data of the number of local lung cancer incidences that are attributable to radiation from radon and its decay products in the residential environment and lung cancer incidences prevented as a consequence of current mitigation efforts in local communities[i]. At the heart of the discussion in one such community is the question whether to adapt a new City Building Code to include mandatory radon mitigation systems in new home construction for the prevention of lung cancer[ii]. This community near the foothills of the Rocky Mountains with a substantially higher than average indoor-air radon concentration compared to the national average could serve as an example in a broader national discussion for other communities after careful comparison of available local radon concentration data with the data presented in this study.

The goal of this study is to calculate local average yearly lung cancer risk rates, to calculate various aspects of the lung cancer risk reduction already achieved due to radon mitigation, and to use these data to predict the residual lung cancer death rates for the community in the next decade. In addition, the purpose of this manuscript is to provide information to other communities that have an increased average indoor-air radon concentration compared to the national average in order to aid in the process whether legislative action is needed or desirable. Finally we want to demonstrate the effectiveness of small to medium sized companies in this context.

STATISTICAL DISTRIBUTION OF RESIDENTIAL RADON CONCENTRATION MEASUREMENTS IN THE AREA.

This manuscript uses in situ radon concentration[iii] reductions obtained with radon mitigation systems that were installed in accordance with the recommendations of the EPA radon mitigation standards[iv] to calculate radon cancer rate reductions, using the committees' two preferred dose-response models presented in BEIR VI, in a community that has a larger average radon concentration in residential structures than the national average. Our data[v] on homes that were not previously tested in the City of Fort Collins, indicate that on the average three out of four tested residential structures have a test result above 4.0 pCi/L. The sample average of our distribution is 6.4 pCi/L with a strongly asymmetric distribution.

All mitigated homes by RHMM with pre-mitigation levels above 4.0 pCi/L were reduced to below 4.0 pCi/L after mitigation. The data does not show a correlation between the final radon concentration values and pre-mitigation levels. Post mitigation radon concentration levels were measured following the EPA protocol including a 24 hour open house waiting period and closed house conditions during and at least 12 hours before the start of the test. After analysis a correlation was found between the final radon concentration and certain details of the building construction that consequently allows for a diversification of mitigation types. The three distinguished types of mitigations are "Phase I-", "Complete-" and "Ideal Mitigation Systems". An increasing degree of success was obtained in reaching a lower radon concentration as is indicated by the average values of measured concentrations in Table 1. The shape and width of the data show nevertheless that neighboring distributions overlap.

SAMPLE STATISTICAL DATA FROM MITIGATED HOMES

Radon concentrations, $\rho_i^{(n)}$, before and after mitigation (n=1,2) for an indiviual house, *i*, were measured via EPA radon measurement protocols partially during real estate transactions and partially for home owners. In total 267 homes are included in this study over the period 1998-2003 that were mitigated by means of active soil depressurization of the sub-slab, a sub-membrane, or mitigated by a combination of the two methods. Using the dose-response factors $\square_m$ from BEIR VI[vi] for the two preferred models of the Committee, a Lung Cancer risk rate was calculated for each residential structure that was mitigated and multiplied with the number of the occupants living in the home N_i at the time of, or immediately before or after the mitigation:

$$L_j^{(mn)} = 1.936 \cdot \alpha^{(m)} \sum_{i=1}^{j} N_i \rho_i^{(n)} .$$

Fig. 1 shows, cumulatively, the Lung Cancer risk rate attributable for the number of homes mitigated for every ten year period in the future. The significance of this curve is the large difference of its slope and the slope of the curve that indicates the calculated residual lung cancer death rate after mitigation. The difference, $L_j^{(m1)}$ - $L_j^{(m2)}$, of the slopes represents the eliminated average lung cancer deaths per home for every period of 10 years in the future. The ratio of the two slopes $L_j^{(m1)}/L_j^{(m2)}$, indicates that an 8.2-fold reduction of lung cancer risk on the average is accomplished due to the combined mitigation effort as measured by the accomplished radon reductions.

The data can be viewed in a different way by calculating the average lung cancer risk reduction for the occupants in each mitigated home

$$R_i = \rho_i^{(1)} / \rho_i^{(2)}$$

and generating the frequency distribution of all individual data.

A mathematical fit to the resulting distribution is shown in Figure 2 which has a strongly asymmetric shape with its maximum near a factor 5 reduction and with 6% of the data indicating a lung cancer risk reduction of more than 40 times. The average of the distribution is 17.5, which is larger than the factor 8.2 mentioned previously because the distribution is strongly asymmetric.

TOTAL AND RADON/RDP CONFOUNDED LOCAL LUNG CANCER RATES

Lung cancer incidence age adjusted rates for Larimer County are available from the county[vii] . Since the survival rate of lung cancer is small the mortality rate after initial diagnosis is only slightly lower. In the calculations presented in this manuscript we have not taken the specific age distribution of the Fort Collins population into account which is a relatively young population because it is a university town. Therefore we have assumed this distribution to be equal to the national age distribution and our results should be compared to the county rates that are age adjusted to the national age distribution. The population in the community is estimated using 1990 data to be 87,941 occupants and in this report we will normalize the resulting data to this number o foccupants by assuming a no-growth scenario[viii]. The age adjusted lung cancer incidence rates reported by the county scaled to the Fort Collins population size is in the bracket 33 to 51 lung cancer incidence per year for the rates reported from 1990-2000.

The most simple model to calculate the Radon/RDP confounded lung cancer rates would be a proportionally scaled population model, ignoring any radon concentration exposure differences to the local compared to the national population , which results in the bracket 5 to 7 lung cancer instances per year. This however underestimates the true rate because the average of the radon concentrations in this community are larger than the nations' average. The Fort Collins data based on the average, 6.4 pCi/L, indicates an increased health risk for its population compared to the national health risk by a factor 5, which we could name the lung cancer risk enhancement factor. Taking this difference in radon concentration averages into account results in 26 to 36 expected radon related lung cancer deaths every year in this community.[ix]

A more accurate value for the lung cancer risk enhancement factor from radon for this City can be calculated by comparing the local measured radon distribution (f(□)), to the national distribution (g(□)) in the BEIR VI report. When assuming a linear dose-response relationship, H(□□□□with □ the dose-response factor and assuming an average occupation per residence, following any of the linear no-threshold models in BEIR VI the lung cancer risk enhancement factor can be calculated using the accumulative risk enhancement factor:

$$\square(r) \square \frac{\int_0^r f(\rho)H(\rho)d\rho}{\int_0^r g(\rho)H(\rho)d\rho} \square \frac{\int_0^r f(\rho)\rho d\rho}{\int_0^r g(\rho)\rho d\rho}$$

This means that the lung cancer risk enhancement factor can be calculated universally and depends only on the distributions f and g and more specifically is independent of the exact value of the dose-response factor □ in the linear model.

The lung cancer risk enhancement factor was calculated as a function of the radon concentration, ρ. The saturation of this curve for large radon concentrations indicates that the lung cancer risk enhancement by radon for the Fort Collins Community is 3.2 larger than the national average. Comparing this to the calculated national rate our calculation shows that this most realistic radon/RDP confounded lung cancer rate is in the 17 to 24 bracket. This rate represents the maximum mitigatable lung cancer death rate under a no-growth scenario and this is the rate that should be recognized as the target for this community to put methods in place to help reduce it.

The three calculated Radon/RDP confounded lung cancer incidences per year in this section for this community are summarized in Fig. 3 and compared with the County lung cancer incidences for all causes scaled for this City. In this comparison the most accurate and relevant calculation includes the radon concentration distributions.

PREVENTED AND PREVENTABLE LUNG CANCER RATES

The need for an ongoing community effort may be judged by the accomplished residual lung cancer death rate due to radon/RDP inhalation. If the residual lung cancer death rate is high a larger effort may be encouraged through the legislative process as through Code changes in new home construction. If the residual lung cancer death rate is low the need for implementation of Code changes may not be appropriate.

In the City of Fort Collins a steady increase of mitigation systems has been accomplished since 1986. Data of the City[x] during the period 1998 to 2000 indicate that approximately 351 homes were mitigated each year. In an effort to make a best estimate it is assumed here that a linear increase of mitigated homes from 1986 until now has been accomplished and will continue in the near future and that the systems installed by all mitigation companies have a similar success in their effectiveness of radon removal. An elementary calculation of which the result is displayed in Fig 4 for the two models shows that in 2003, approximately 6 to 8 lung cancer deaths are prevented every year depending on the BEIR VI model chosen in this community by past mitigations. This is indicated by the cross shaded shape in order to show that even if there was an immediate freeze on all future mitigations, the mitigations in the past would continue to save lives among the occupants in the mitigated homes. The shape of the distribution shows that if a linearly increasing number of homes are mitigated every year, a quadratically increasing number of lives will be saved in each future year. Following this scenario the preventable rate would be in the bracket 16 to 21 lung cancer deaths prevented per year in the year 2013. The true rate will be smaller because the average of the pre-mitigation radon concentrations of the mitigated homes in the future will decrease when more homes have been mitigated. Extrapolation beyond 2013 is not realistic because of these and other unknown parameters. For example the rate increases if currently discussed legislative requirements of new home construction are implemented and will show a saturation at large values. A similar calculation based on the averages of the known radon concentration distributions results in 14 to 20 preventable lung cancer deaths per year. Both values for 2003 and 2013 are shown in Fig 3.

RESIDUAL RADON/RDP LUNG CANCER RATES

The analysis in this study shows that the expected residual lung cancer death rate with radon as a confounding factor, given the measured radon distribution in homes in Fort Collins compared to the national distribution, is currently estimated in the bracket 11 to 16 lung cancer deaths per year. The expected residual lung cancer death rate in 2013 can be calculated by using the data presented in Fig 1 and by dividing the preventable radon lung cancer rate by the factor 8.2 that was extracted from these data. The result will be in the bracket 2 to 3 lung cancer deaths per year in the year 2013. This reduction from the current 11 to 16 lung cancer deaths per year means that in this small community by a continued effort on the average one additional lung cancer death can be prevented at least every five weeks. Formulated this way may best help to illustrate the urgency for the ongoing radon mitigation effort. Based on the data presented here this effort is also expected to result in a lowering of the current total lung cancer death rate in this community by a substantial fraction of 30%.

ACKNOWLEDGMENTS: The presented data could have not been measured without the many who helped to load and unload the trailer, fight the spiders and seal the radon barriers meticulously in those 4- and 2-foot crawl spaces, those who caulked all expansion joints, control grooves and cracks in basement slabs and spend time in those sauna-like attics in the summer. I am indebted to Heather Fleck, Shaun McDonnell, Juan Moreno and others for their assistance and to all home owners who cleaned up their crawl spaces and basements before the start of our mitigation work.

REFERENCES

---

[i] Fort Collins City Council meeting, July 2002, and May 2003.

[ii] On July 20, 2004 the Council of the City of Fort Collins adopted the IRC 2000 building code to be effective January 1, 2005, with an amendment requiring passive mitigation systems in New Home Construction.

[iii] The term "Radon concentration" which is measured in terms of the "radon (radio-) activity density" and is defined as the rate of decay by radon atoms per unit of volume, often measured in units pCi/L or Bq/m^3, in which 1 pCi/L=37 Bq/m^3.

[iv] Radon Mitigation Standards EPA 402-R-93-078, Oct 1993, Rev. April 1994

[v] Data gathered by the City of Ft. Collins shows that of more than 10,000 tests gathered approximately 75% had a radon concentration larger than 4.0 pCi/L.

[vi] National Academy of Sciences: The Commission on Biological Effects of Ionizing Radiation (BEIR) VI " The health effects of exposure to Indoor Radon."

[vii] Larimer County, with Fort Collins as seat, has a population of 221,725 (1996) World Almanac, 1998. The yearly Lung Cancer Incidence rates for Larimer County during the decade 1990-2000 are available via the Larimer County website and vary from a low 37.6 to a high of 57.7 lung cancer incidences per year per 100,000 occupants. Source: Colorado Department of Public Health and Environment - Colorado Central Cancer Registry.

[viii] Resulting rates will have to be scaled with future population changes.

[ix] Weighed risk factor for public includes smokers and no-smokers.

[x] Radon Program Review 2001: City of Fort Collins Natural Resources Department (CPES), March 2001