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INDOOR RADON AND LUNG CANCER IN MINNESOTA

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Elevated indoor radon concentrations and long periods of indoor occupancy produce median lifetime exposures for Minnesotans, 40 WLM, comparable to groups of modern uranium miners. Excess lung cancer rates in rural counties indicate positive correlation with exposure at a rate that is also comparable with underground miners.

INTRODUCTION

Radon-daughter exposure has been linked to excess lung cancer rates in underground miners (NAS BEIR IV, 1988). Epidemiological studies of non-occupational radon (^{222}Rn) exposures have been unable to reach definitive conclusions about the relationship between indoor radon and lung cancer (Borak and Johnson,1988). Although most of these studies indicate some positive correlations between radon exposure and lung cancer, a few show either no significant correlation or a negative correlation. Even well designed case-control and cohort studies have not accurately reconstructed individuals' total exposure since they use only contemporary radon measurements.

Natural and human conditions combine to make Minnesota a favorable place to study the effects of chronic human exposure to indoor radon and its decay products.

Minnesota homes contain radon concentrations approximately three times higher than the U.S. average (Steck 1987). Elevated indoor radon concentrations can be found in homes throughout the state. A multi-year study of the long-term radon concentration in 208 homes located throughout Minnesota found that the annual-average radon concentration in basements was 200 Bq m^{-3} (5.6 pCi L^{-1}), 110 Bq m^{-3} (3.0 pCi L^{-1}) in first-floors, and 140 Bq m^{-3} (3.8 pCi L^{-1}) in living spaces. The annual-average radon concentration in the living spaces of the median home was 100 Bq m^{-3} (2.8 pCi L^{-1}) which is well above the national median (Nero, et al. 1986)(see Figure 1). Other Minnesota surveys showed generally similar basement radon distributions (Tate 1988, Heystek 1989). Unfortunately neither of these surveys measured annual-average, living-space radon concentrations and can't be used to estimate long-term exposures. Within Minnesota, large regions (multi-county sized, i.e., 10^4 square miles) appear to have similar indoor radon distributions (see Figure 2). However, significant differences have been observed between smaller areas (town sized, i.e., 10^2 square miles) (see Figure 3). This local geographic variation, coupled with reasonably uniform regional ethnicity and lifestyles, would make it easier to select individual cases and controls for an epidemiological study in Minnesota.

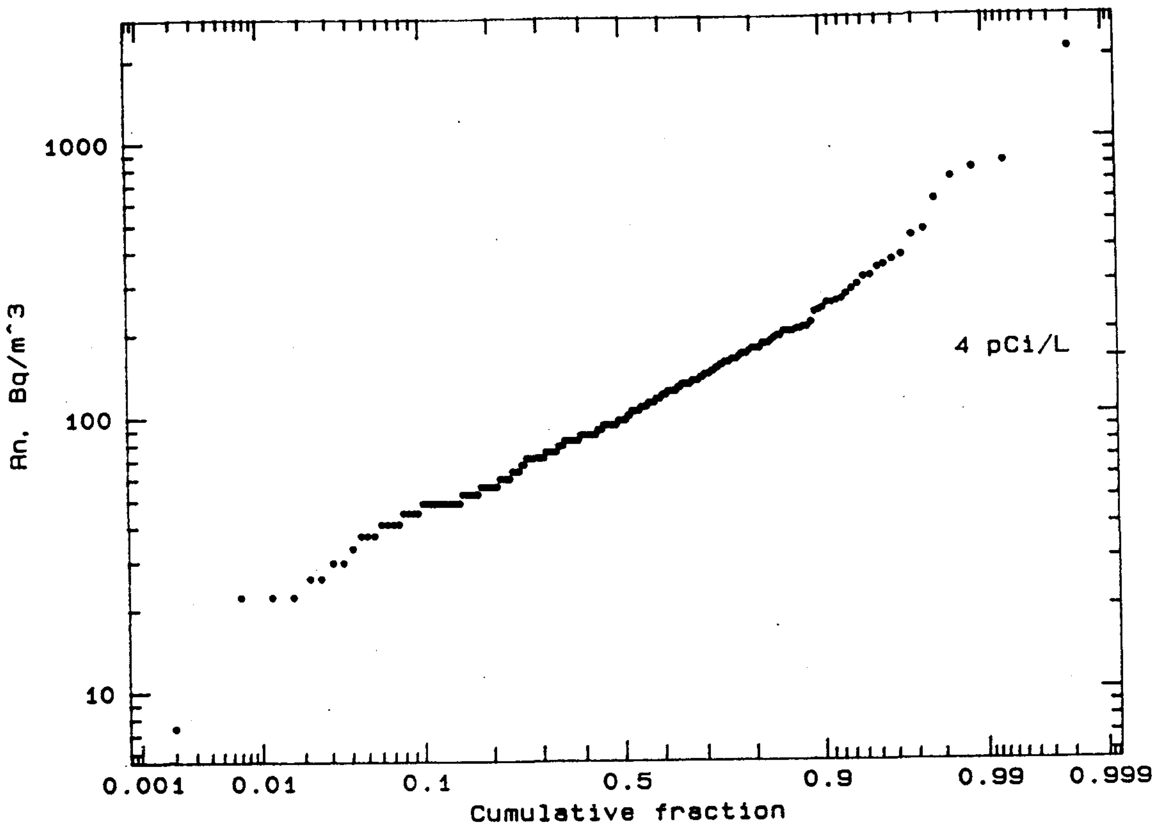

Fig. 1. Distribution of indoor ^{222}Rn in the living spaces

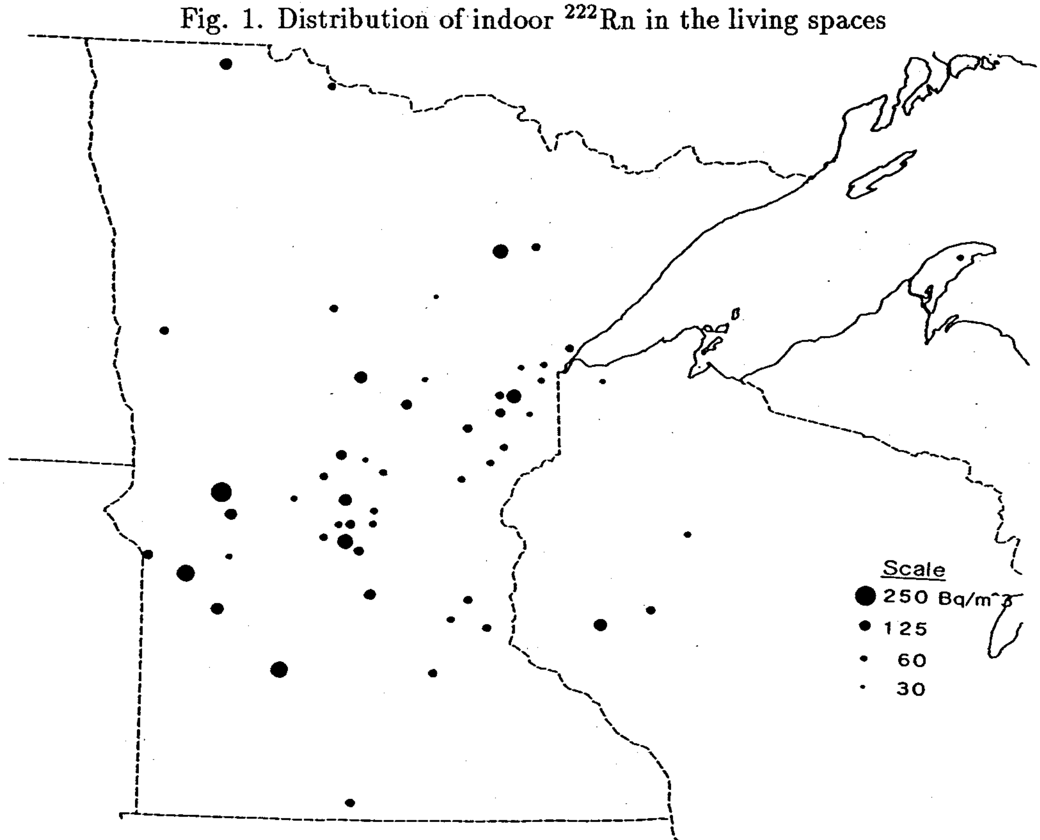

Fig. 2. Geographical distribution of towns sampled. Dot radius scaled to the median value of the indoor ^{222}Rn in each town.

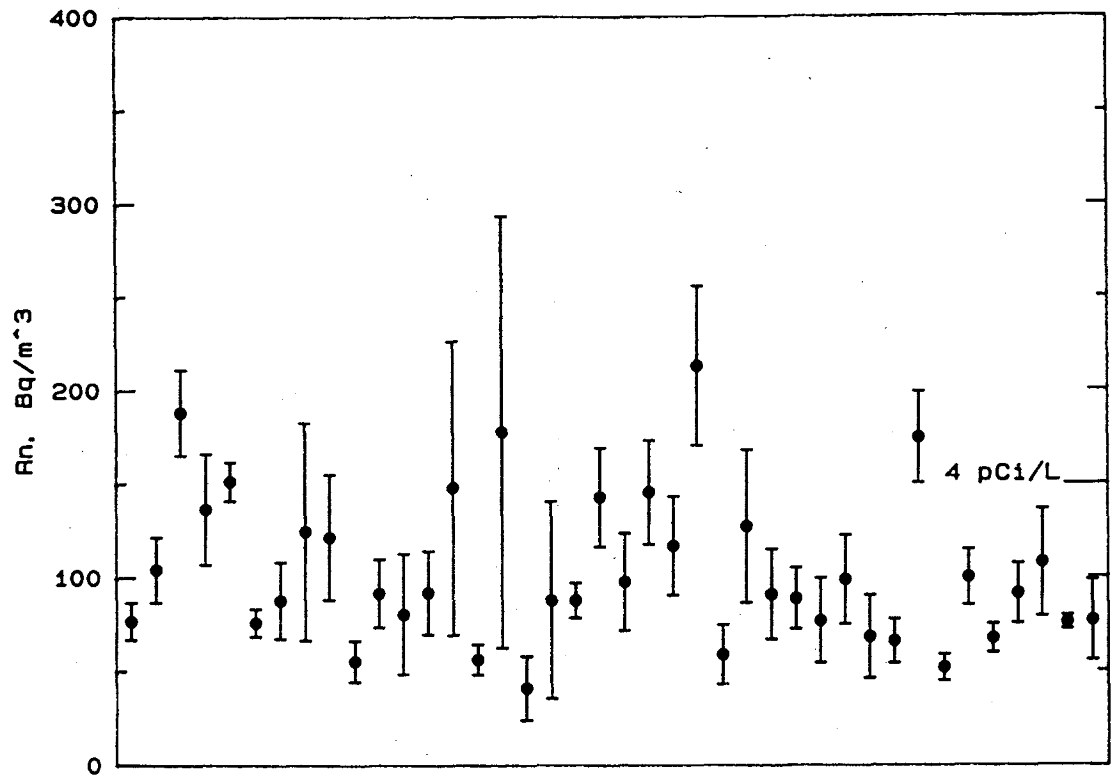

Fig. 3. Median indoor ^{222}Rn concentrations for towns in survey. Error bars reflect the uncertainty in the median.

Minnesotans tend to spend significant portions of their lives in elevated radon environments. Minnesota's mid-continental climate encourages indoor living during both winter and summer. Severe winters encourage tight, energy-efficient housing. Minnesota's rural areas contain a stable, long-lived population that spends significant time indoors. During the past 40 years, few people have migrated **into** rural Minnesota. Intrastate migration generally takes place from the rural counties to the metropolitan counties or from the farm to the nearest town. Thus, it is likely that lung cancers found in rural areas will belong to long-term local residents.

In the recent past, Minnesotans have generally smoked less than most Americans. In addition, the outdoor air is relatively clean in rural areas. Yet, the statewide lung cancer rate (age-adjusted rate of approximately 400 cases per year, per million residents) is not significantly different from the national average rate.

The estimated average decay-product exposure of a 57 year-old Minnesotan is 0.14 J h m^{-3} (40 WLM), using standard assumptions for decay-product equilibrium ratios and occupancy (0.5 and 70%). This exposure is in the range of the average occupational exposure of several cohorts of uranium miners who were included in previous epidemiological studies (BEIR IV 1988, Hoffman et al. 1986, Cohen 1982, Sevc, et al. 1988).

ANALYSIS

Twenty-six towns, located in thirteen counties, were selected for the analysis from the total data set based on the town's sample size (more than 4 houses) and rural location. Seven of the thirteen selected counties contained more than one sampled town. County-average lung cancer rates were calculated from five years of Minnesota Health Department (MHD) reports (Minnesota Health Statistics, 1975, 1979–82). In order to compare lung cancer rates for non-occupational individuals at risk with the occupational (miners) data, the non-occupational rate was calculated for persons aged 44 years or more by dividing the observed county lung cancer rate by the population exceeding 44 years old as reported in the 1980 census. These rates ranged from 650 to 1250 deaths per year per Million-persons at risk (D y^{-1} Mp^{-1}). Radon decay product exposures during the average lung-cancer victim's lifetime (57 years) ranged from 0.1 to 0.4 J h m^{-3} (30 to 110 WLM). Figure 4 shows the result of a linear least-squares fit of exposure-response data. Linear regression analysis indicates a positive correlation that is significant at a $p = 0.1$ confidence level. A least squares linear fit yields a slope, (7 ± 2 D y^{-1} Mp^{-1} WLM^{-1}), that is similar to the slope, 7 ± 1 D y^{-1} Mp^{-1} WLM^{-1} of the occupational response data, shown in Figure 5. The fit's intercept, 570 ± 70 D $y^{-1}Mp^{-1}$, is close to the 1950–69 national average lung cancer rate for persons in their mid-fifties (approximately 500 D y^{-1} Mp^{-1}). A separate analysis of the age-adjusted and sex-specific lung cancer rates for these counties over a slightly different interval, 1980-85, showed correlations at similar confidence levels.

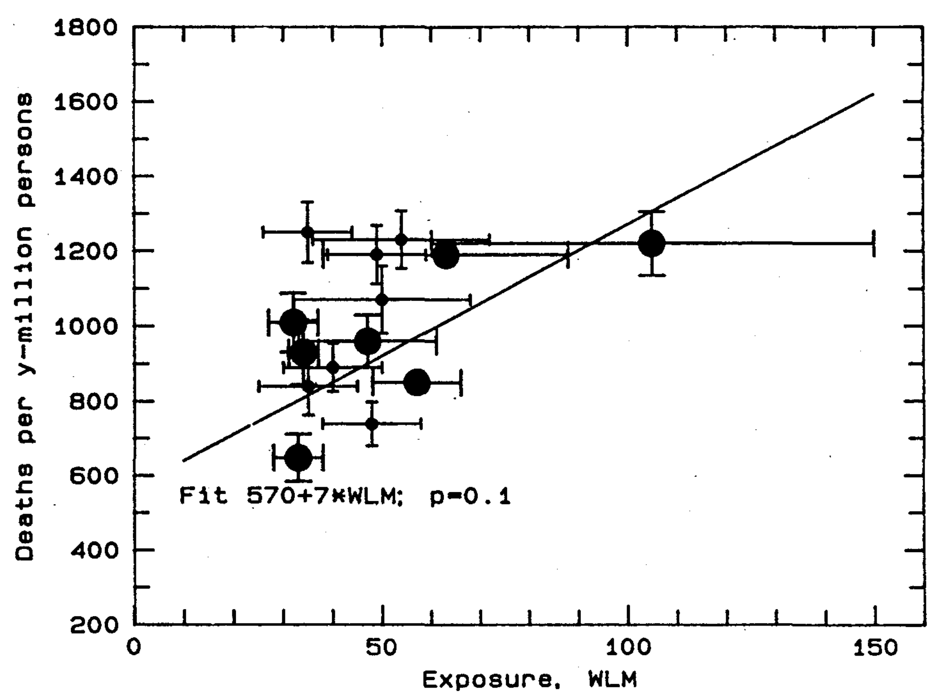

Fig. 4. County-average lung cancer rates and estimated lifetime exposure. Error bars reflect sampling errors only. Large dots show counties that had more than one town sampled.

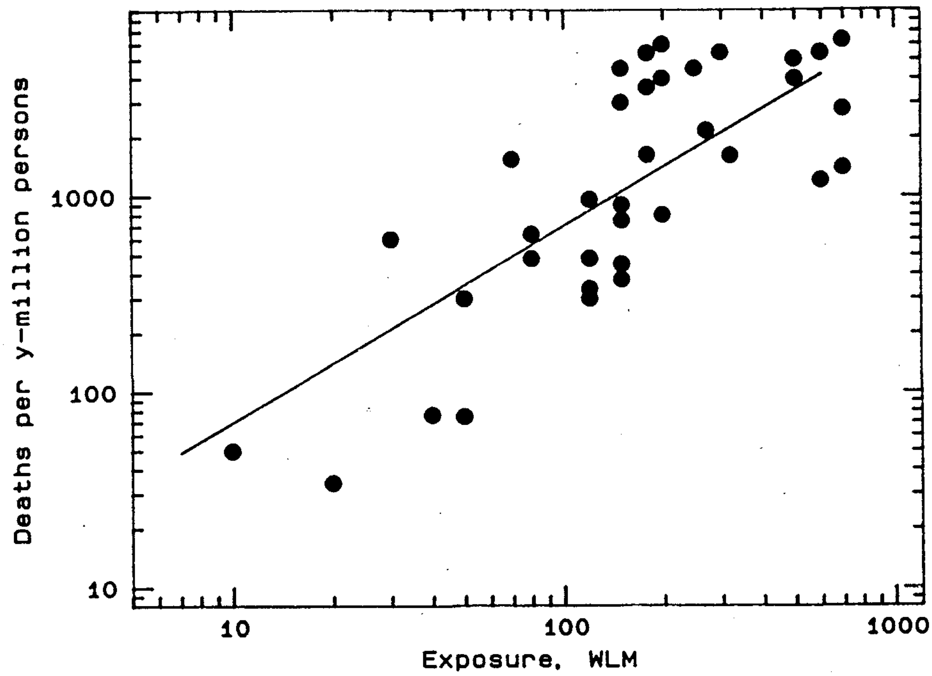

Fig. 5. Excess occupational lung cancer rates. (Data extracted from Hoffman et al. 1986)

DISCUSSION

In order to compare the general population's exposure-response data with that of underground miners, three models were used to convert the non-occupational total lung cancer rates to excess lung cancer rates. Unfortunately it was impossible to separate the data by smoking patterns or gender. Therefore, the most reasonable model assumed that smoking and gender rates are uniform throughout the state. In this model, called the empirical model, the excess lung cancer rate was calculated by subtracting the linear least squares intercept from the total lung cancer rate. These empirical model excess lung cancer rates, 90 to 660 D y^{-1} Mp^{-1}, overlap the occupational rates, 80 to 950 D y^{-1} Mp^{-1}, at similar exposure (see Figure 6). In a second model, labelled the homogeneous model, it is assumed that Minnesota smoking and gender patterns are the same as the national patterns and that the non-radon lung cancer rate was approximately the 20-yr national average (1950-69) for people in their fifties, 500 D y^{-1} Mp^{-1}. The excess rates in this homogeneous model, 150 to 730 D y^{-1} Mp^{-1}, are still of the same magnitude as both the empirical model and the miner data (see Figure 7). A proportional model was used to try to account for variable smoking patterns within the state. In this model, that assumes that 80% of the total lung cancer rates are smoking related, the excess lung cancer rates are of the same order of magnitude as the other models, ranging from 130 to 240 D y^{-1} Mp^{-1}.

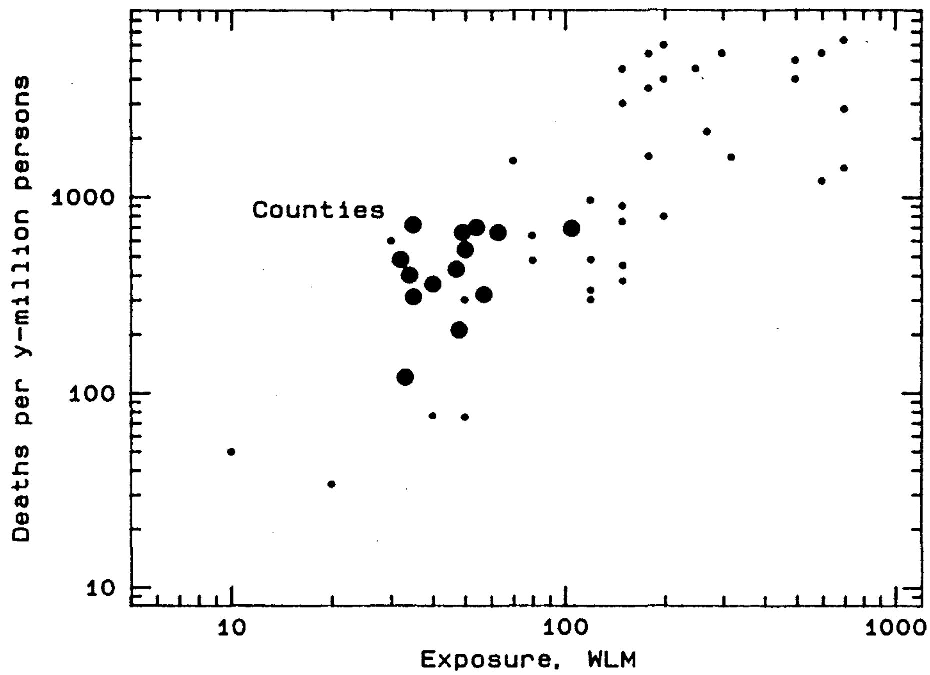

Fig. 6. Excess lung cancer rates for underground miners (small dots) and Minnesota counties (large dots).

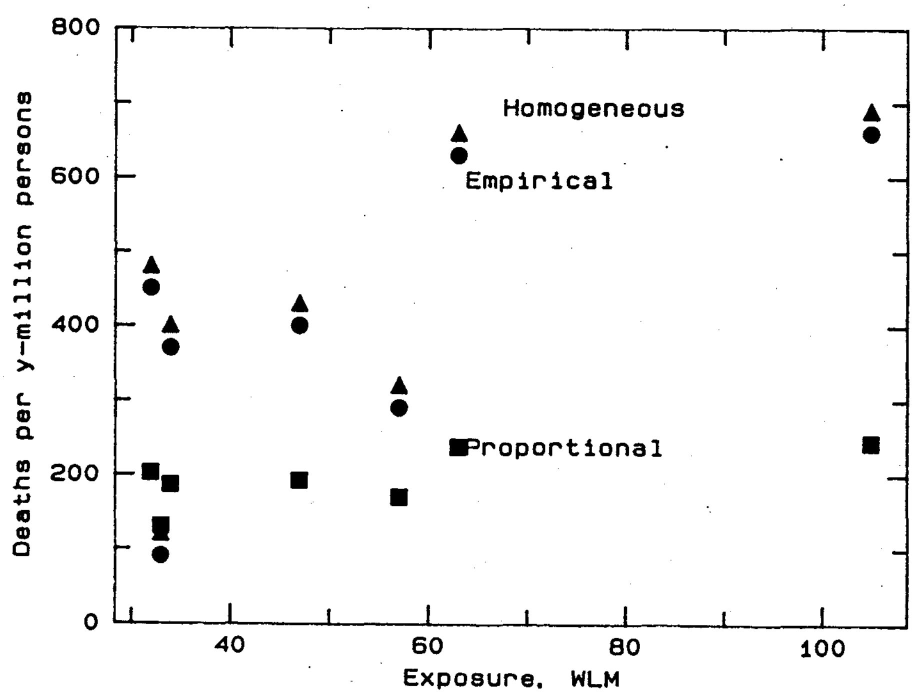

Fig. 7. Comparison of three models for estimating excess lung cancer rates from observed lung cancer rates.
Empirical model (•); Homogeneous model (▲); Proportional model (■).

Caution must be used in interpreting the results of this study. As in any ecological epidemiological study, individual lung cancer victims' exposures may not be accurately estimated from the geographical average of the annual radon concentration in current dwellings. Significant spatial and temporal variations could seriously distort the estimated exposures. In an attempt to reduce the temporal uncertainty, we are currently studying the annual radon concentration variation in Minnesota homes and the accuracy of a retrospective radon detection technique, ^{210}Po activity on hard surfaces, in reconstructing past radon environments. Spatial uncertainties could be reduced in future studies by selecting individual cases or cohorts whose residences are available for analysis. As in any epidemiological study with a small sample size, correlation confidence levels suffer from large uncertainties. However, the trend of the data suggests to me that the relationship between indoor radon exposure and lung cancer in Minnesota is strong enough to warrant intensive study.

References

- Borak, T.B.; Johnson, J.A. Estimating the risk of lung cancer from inhalation of radon daughters indoors:review and evaluation. National Technical Information Service, Springfield, VA, USA EPA 600/6–88/008; 1988

- Cohen, B.L. Failures and critique of the BEIR III lung cancer risk estimates. Health Phys. 42:267–

- Hoffman, W.; Katz, R.; Chunxiang, Z Lung cancer risk at low doses of alpha particles. Health Phys. 51:457–468; 1986.

- National Academy of Sciences. Health risks of radon and other internally deposited alpha-emitters. BEIR IV National Academy Press, Washington, D.C.; 1988.

- Minnesota Department of Health. Minnesota Health Statistics. Minneapolis MN; 1975, 1979–1982.

- Nero, A.; Schwehr, M; Nazaroff, W.; Revzan, K. Distribution of airborne radon-222 concentrations in U.S. homes. Science 27:992–997; 1986.

- Sevc, J; Kunz, E.; Tomasek, L. Cancer in man after exposure to Rn daughters. Health Phys. 54:27-46; 1988.

- Steck, D.J. Variation of radon sources and indoor radon along the southwestern edge of the Canadian Shield. Environ.Int. 15:271–279; 1989.

- Tate, E. Survey of Rn in Minnesota Homes. Minnesota Department of Health, Minneapolis, MN; 1988.